No. 3 *It is requested that this book may be considered confidential.*

NOTES

ON

DEFENCE BY SUBMARINE MINES,

BY

LIEUT.-COL. R. H. STOTHERD

ROYAL ENGINEERS,

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PREFACE.

SINCE the first edition of this book was published, in March, 1871, a very considerable advance has been made in perfecting the apparatus and instruments required for carrying out that system of Defence by Submarine Mines, which was originated, and has been gradually brought to its present state, at the School of Military Engineering, Chatham. Since that time, the apparatus adopted has been thoroughly experimented upon by the Torpedo Committee, which was specially appointed to carry out this duty and to superintend the purchase of a small reserve of stores of approved patterns, for the defence of military ports. The whole of the apparatus employed has now received the approval of the War Office authorities.

In compiling the contents of this book, most valuable assistance has been afforded by the Officers of the School of Military Engineering, as well as many of the Corps of Royal Engineers generally. Much information has also been obtained from the Report of the Floating Obstruction Committee, from the proceedings and experiments of the Torpedo Committee, and from the Instructors in Electricity on board H.M.S. "Excellent," at Portsmouth. In addition to those whose names are mentioned in the preface of the first edition, as having contributed to the work, it is but due to those who have assisted in the development of the system of Defence by Submarine Mines hereafter described, to mention the names of Captains S. Anderson and R. Y. Armstrong, R.E., F. A. Abel, Esq., F.R.S., Chemist to the War Department, Commanders J. A. Fisher and H. B. Stewart, and Lieut. W. H. Hall, R.N., who have given a large amount of assistance on all occasions. The illustrative lithographs have been very neatly drawn by Corporal B. Butler, of the Royal Engineers.

The science of Defence by Submarine Mines is still eminently progressive, and though a certain amount of perfection has been attained, it is very evident that considerable improvements may be introduced. In the matter of the electrical testing of mines in position, for example, much may still be done, and a comparison of the crude ideas, with which the system was started only a few years ago, with the present degree of perfection in the apparatus, is a proof that considerable improvements may yet be introduced.

For obvious reasons it is considered necessary to make this this book confidential; but while confidential as regards those whose possession of the information might benefit a possible enemy, it is to be hoped that it may be circulated among, and be discussed to the utmost by, those Officers to whom the defence of the British Empire, colonial as well as home, may be entrusted. The disastrous result of extreme reticence in warlike matters, which was a prominent feature during the second French Empire, is a matter of such recent occurrence as to need no comment. The state of things then existing in France is most graphically described by Baron Grivel, Capitaine de Vaissean of the French Navy, as follows:—

"This was the period, when secrecy in the matter of warlike matérial was raised to the rank of a law of public safety. This silence, too rigidly preserved towards our own Officers, was generally a complete farce with respect to Foreign Officers; whilst the almost absolute prohibition to our writing on the Army or Navy, or discussing new inventions, contributed to draw the great mass of our Officers away from the study of subjects intimateiy connected with their profession."

The following books have been consulted in drawing up this work:—

Notes on Submarine Mines, commonly called Torpedoes, by Captain Harding Steward, R.E., Jackson & Son, Woolwich, 1866. *A Treatise on Coast Defence,* by Von Scheliha, Lieut.-Col. of the Army of the late Confederate States of America, E. & F. Spon, London, 1868. *Report on Active Obstructions for the Defence of Harbours and Channels, &c, and on the Employment of Torpedoes, for Purposes of Attack,* by the Committee on Floating Obstructions and Submarine Explosive Machines, published confidentially by the War Department, 1868. *Submarine Warfare, Offensive and Defensive,* by Lieut.-Commander J. S. Barnes, U.S. Navy, D. Von Nostand, New York, 1869. *Instructions for the*

Management of Harvey's Sea Torpedo, E. & F. N. Spon, 48, Charing Cross, London; J. Griffin & Co., Portsmouth; and J. R. H. Spry, Devonport, 1871. *A Treatise on Electricity and the Construction and Management of Electrical and Mechanical Torpedoes*, by J. A. Fisher, Commander, Royal Navy. Second edition, revised and enlarged, published by the order of the Lords Commissioners of the Admiralty, 1871.

R.H.S.

SCHOOL OF MILITARY ENGINEERING, CHATHAM,
27TH FEBRUARY, 1873.

APPENDIX.

WHILE this book was in the press, certain additional information, bearing materially on the question of submarine mines, has been obtained through the agency of experiments carried on by the Torpedo Committee. There are also certain points which demand a little further explanation. It is proposed, therefore, briefly to allude to them in the form of an appendix.

Experiments on explosives in December 1872.

Some very interesting experiments, carried out at Weston-Super-Mare early in December, 1872, throw considerable light on the relative values of gunpowder, picric powder and compressed gun-cotton as submarine explosive agents.

The objects of these experiments were :—

1st.—To obtain a comparison of the explosive force of gunpowder, picric powder and compressed gun-cotton, when exploded under similar conditions.

2nd.—To obtain a comparison of the explosive force of nitrated gun-cotton and of compressed gun-cotton, when exploded under similar conditions.

3rd.—To ascertain the effects of the depth of immersion upon the explosions, as indicated by the dimensions of the craters produced in the mud, and of the columns of water thrown up.

4th.—To ascertain whether the explosive power of compressed gun-cotton is affected by its employment in a damp condition, viz., containing not less than 20 per cent. of water.

5th.—To ascertain whether compressed gun-cotton can be completely exploded when in a thoroughly wet state, the spaces between the individual masses which compose the charge being filled with water.

Previous experiments had shown that no reliable results were to be looked for from the explosion of small charges :—it was therefore decided to make use of 100lb. charges of each explosive, these to be fired by detonation.

Weston-Super-Mare bay was selected as the place for the experiments, for the following reasons :—

1st.—Because the bottom, which is of mud, seemed to be fairly uniform in depth and character, and of sufficient tenacity to

preserve its shape, after disturbance, for two or three tides.

2nd.—Because the bottom was so flat as to be practically level within the limits of each experiment.

3rd.—Because there was a rise and fall of tide sufficient to permit a careful examination of the craters, the bottom remaining for several hours uncovered to a considerable distance from the shore.

4th.—Because there was but little traffic to be interfered with by, or to interfere with, the experiments.

The results obtained are given in tables A and B, the former showing these under the same head of water, and the latter under different heads of water.

The dimensions of the columns of water were obtained from instantaneous photographs, those of the craters by actual measurement.

The amount of work done in the displacement of water and mud, is arrived at by supposing so many tons of water and so many tons of mud raised a certain number of feet; the interior of the column of water being supposed to be occupied by an egg-shaped space of gas, the distance of the centre of gravity of the column at the moment of explosion, above the centre of gravity of the water in the truncated cone before its displacement, gives the height to which it is lifted; and similarly the height of the centre of gravity of the mud raised out of the crater and deposited round the edge, above that of the same mud before disturbance, gives the height to which this latter is lifted.

This idea of calculating the amount of work done is due to Lieut. Abney, R.E., his assumption as regards the shape of the gas space is of course hypothetical, but the results, if not absolutely correct, may certainly be accepted as a fairly approximate comparison of the amount of work done in each case.

It has been conclusively established by experiments which Mr. Abel, Chemist to the War Department, has instituted, that the incompressibility of water operates very favourably, under particular conditions, in transmitting instantaneously the force developed by detonation, from an exploding mass to other masses separated from it by water.

The successful explosion of the charge of wet gun-cotton, appears correctly attributable to this power of transmitting force possessed by water. The result furnished by the charge of wet gun-cotton is not, however, directly comparable with that furnished by the others, because this particular charge (No. 24) was $\frac{1}{4}$ greater in amount, (122lbs. instead of 100lbs.), and because, in all the other charges there was a considerable air space within the case, the latter not being completely filled.

The very inferior result furnished by the charge of picric powder (No. 23) exploded at a depth of $13\frac{1}{2}$ feet, was no doubt due to imperfect ignition. This charge was confined in an Indian-

rubber bag, which offered no resistance to the pressure developed by the first ignition of the powder, and there appears but little doubt that the detonating fuzes employed, were not sufficiently powerful to determine, with certainty, the actual detonation of such charges of picric powder under these circumstances. Large numbers of unconsumed grains of picric powder were found on the mud all round the crater formed by this charge. In another instance (No. 22) the detonation proved more successful, the charge being also in an Indian-rubber bag. A charge of gunpowder, also in an Indian-rubber bag, produced small results—it was probably not all ignited.

The following are the conclusions arrived at by the Torpedo Committee, as the result of these experiments:—

1st.—The explosive force of picric powder is much superior to that of gunpowder as a charge for submarine mines, when both are exploded under similar circumstances.

2nd.—The explosive force of picric powder is but little inferior to that of ordinary compressed gun-cotton, when both are exploded under similar circumstances.

3rd.—The estimate of the explosive force of ordinary compressed gun-cotton deduced from previous experiments, is corroberated by the results of these experiments.

4th.—The explosive force of nitrated gun-cotton is probably at least the same as that of ordinary compressed gun-cotton; no positive conclusion can, however, be deduced from the single experiment made.

5th.—The depth at which a charge of 100lbs. produces the greatest lateral effect on the mud, appears to be:—

Of gunpowder about 11 feet.

Of picric powder between 11 and 12 feet.

Of ordinary compressed gun-cotton between 11 and 15 feet.

6th.—The explosive force of damp gun-cotton, (containing not less than 20 per cent. of moisture), appears, in the single experiment made, slightly less than that of ordinary compressed gun-cotton.

7th.—A charge of gun-cotton in a completely saturated state—the spaces between the individual discs being filled with water—can be exploded, but no positive deduction as to result can be drawn from a single experiment.

8th.—The full explosive force of picric powder is developed when the charge is exploded in a weak case, such as an Indian-rubber bag, provided the detonation of the charge be secured.

In considering the results obtained with the charge of wet gun-cotton (No. 24), it must not be assumed that very leaky iron cases may be used to contain the charges for submarine mines. This is a point which requires very careful investigation, and there are other contingencies which must be considered in connection with it. It must be borne in mind also, that only a single experiment has yet been made with a wet charge of this size.

In pages 2 and 3 where allusion is made to the Russian and American submarine mines, it is stated (page 3) that the former (the Russian) were arranged for mechanical ignition. It must not be inferred from this that they were exclusively designed for mechanical ignition: a few were arranged to be fired by electricity, on a plan proposed by Dr. Jacobi. *Russian electrical mines.*

A smaller size of oblong sinker, similar in form to that described at page 74, has recently been ordered by the Torpedo Committee to fit the 250lb. ground mines. Its weight is about $2\frac{1}{2}$cwt. *Oblong Sinkers.*

The nomenclature and colours of the several of electric fuzes, have been altered from those given in pages 104 and 105, as follows:— *Nomenclature of fuses*

			No.	Mark.
Fuzes, electric.		Abel's, for mines, color of fuze black	1	II
		Submarine, colour of fuze head black	2*	I
		Platinum wire, colour of fuze head white	3*	I
Detonators	Electric	Abel's, for mines, colour of fuze entirely red ...	5	I
		Submarine, colour of fuze head blue, point red ...	6	I
		Plat. wire, colour of fuze head white, point red ...	7	I
		Abel's for Bickford's fuze, color red...	8	I

In some of the forms of single, electric, armoured cable, more recently purchased for the reserve of stores, described at page 118, each of the wires composing the armouring has been covered with tarred tape, instead of tarred Russian hemp, with a view to a reduction of the diameter of the complete cable. Either tape or hemp, however, answers the purpose required, and sufficient experience has not been obtained to enable a decision to be given in favour of one or the other. *Armouring of electric cables.*

With reference to the use of grease in the formation of water-tight and insulated joints, which has been several times suggested for this purpose in the chapter on Water-tight and Insulated Joints and Connections, page 132 and those following, it must be borne in mind, that grease is only applicable where a temporary joint is to be made; for example, where a joint is required to connect a charge to be put down and fired at once. Grease acts prejudicially on Indian-rubber, and must never be employed where a joint of a more permanent character, to be left under water for any considerable time, is required. Under such circumstances, any of the more permanent joints, described in this chapter, would be employed. *Use of grease in forming temporary insulated joints.*

*Nos. 2 and 3 are only made for experimental and instructional purposes, for which it is safer to use them than to employ the service detonators, which are charged with fulminate of mercury.

Connections of circuit closers.

The description of the mode in which the action of tl closer is secured, together with the several connection internal apparatus, is given at pages 155 and 241. T (page 241) is preferable to the former, being more deta accurate, especially with regard to the testing and signalli connections.

Improvements in firing battery.

A considerable advance has been effected in the improv the firing battery, described at page 215. The suggestio by Qr.-Mr. Sergt. Mathieson, (see page 218), have been in principle, and some further modifications are now und with a view to an arrangement being made, by which a zi may be withdrawn for examination, or may be replace fresh one, without disturbing the other parts of the cel results obtained with this latest improvement indicate probability of success.

Telescopic firing arc for converging station.

In addition to the telescopic firing arc, described at pa and shewn in Plate LXVIII., which was designed for the station, a special form, of simpler construction, has been a for the converging station of a system of mines to be fi cross-bearings. This is shown in *Plate* LXVIII., *Figs.* 5 It is similar in principle to that for the firing station, the however being smaller and there being no arm from the u bearing the telescope to the front contact sight. In oth spects the parts are made precisely similar and are interch able. They have been lettered to correspond with thos *Figs.* 1 and 2.

The sight, *Plate* LXVIII., *Fig.* 4, has also been slightly alt The hole in the centre has been omitted, and the alignme now taken by means of the V formed mark on the top.

Mode of mooring electro-contact mines.

Improvements are required in the mode of mooring the elec contact mines, as described at page 75. The motion produced the water has been found to act prejudicially, on the elec cable of the branch, connecting the mine to the main elect cable, and on the mooring arrangements generally.

ERRATA.

Page 118, line 19, for tanned read tarred.
„ 240, „ 21, „ *Fig.* 7 read *Fig.* 8.
„ 259, „ 38, „ *Plate* LXVII. read *Plate* LXXVII.
„ 322, „ 25, „ running read ramming.
„ 342, „ 26, „ in place read in plan.

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CHAPTER I.

Introductory.

THE idea of attacking ships by submarine explosions is by no means new; several forms of apparatus have, from time to time, been designed with this object in view: it is only, however, within the last few years that really effective means have been devised, either for attack or defence by such agencies, and there is no doubt that the facilities afforded for ignition by Electricity have materially aided in the accomplishment of the object to be attained.

It will be interesting briefly to notice the several attempts which have been made, since the first attack by weapons of this nature, and to study the gradual improvement which has been effected in this branch of warfare.

First recorded attack by Drifting Torpedoes.

The idea of the attack of ships by these means was first attempted, that of the defence of channels by stationary mines being comparatively a recent conception. The first recorded attack on a fleet, that I have been able to discover, occurred during the war of American Independence, on the 7th of January, 1778, when a number of kegs, filled with gunpowder and arranged to be fired on contact by a simple gun-lock, were floated down upon the British ships in the Delaware. There is a very graphic account given of this in Commander Barnes', (United States Navy), book on *Submarine Warfare:* the consternation and confusion which ensued shows that, even in this very primitive form, an attack by numerous drifting Torpedoes proved effective. Early in the present century, Fulton, an American, devised a scheme for the attack of vessels by means of what are now termed "Torpedoes."

Fulton's Torpedo.

A description of his proposals may be found in the Confidential Report of the Committee on Floating Obstructions, published by the War Office in 1868. His ideas were submitted for the consideration of several European Governments, including our own, as well as to that of the United States of America, but were not received with favour. Subsequently, Warner proposed a machine of this nature, with which an experiment was made against a vessel called the "John o'Gaunt." This experiment was successful as far as the destruction of the vessel attacked was concerned, the condemnation of Warner's scheme is supposed to have been

Warner's Torpedo.

caused chiefly by the extremely dangerous nature of the explosive employed, which rendered its general application impracticable; it was too dangerous to be stored or used in any ordinary manner. The action of the apparatus is said to have depended on percussion, and to effect this the vessel was towed over it. Considerable secrecy was observed with reference to this scheme.

Chinese Torpedo.

The idea of this means of attack, though so far not successfully carried out, was not, however, given up. Machines to produce submarine explosions exist among the Chinese. One of these, arranged to be set in action by means of water bellows, in connection with a simple mechanical igniting apparatus, was exhibited by the Rev. G. Beal, Chaplain, Royal Navy, in the Lecture Theatre of the Royal United Service Institution, on the evening of the 19th of June, 1871. It is supposed to have been invented by the captain of an American merchant ship, and sold by him to the Chinese. There is also a very curious description of this and other forms of apparatus, published in the Chinese language, one or two copies of which have found their way to this country.

Russian Submarine Mines, as used in the Baltic during the last war.

During the recent war with Russia, in which Great Britain took so prominent a part, the idea of a system of defence by submarine mines, or stationary torpedoes, seems to have been first originated. These were extensively used in the defence of the Baltic ports. The apparatus employed was comparatively crude and clumsy, as compared with our present ideas, and the results obtained were small and produced but little effect as regards the general conduct of the operations of the attacking fleets. Though some of the vessels were struck, none were sunk and no very serious damage was done, and subsequent experience has demonstrated, that this want of success was due to the defective construction of the igniting apparatus and the small charges of powder employed. We have reason to know that the Russians of the present day have improved immensely on the machines then used, they are probably now well advanced in this form of warlike apparatus, and are making every effort to perfect their systems both for offence and defence.

American Torpedoes and Submarine mines.

Again, during the recent civil war in America machines of this nature, both offensive and defensive, were used by the Federals and Confederates, especially by the latter, with very much more decisive results. Several of the Federal vessels were sunk, and many were so seriously damaged as—for the time—to be placed *hors de combat*. A very excellent description of the means employed during this war has been given by Captain Harding Steward, Royal Engineers, in his valuable pamphlet on *Submarine Mines*. The operations carried on during this war show a decided advance as regards the construction of apparatus and mode of ignition on those employed by the Russians, and much larger charges of powder were used. This last is a very decided step in advance; the Russians only used charges of 8 or 9 lbs. of gun-

powder, and we now know from experiment that such a charge would produce no decisive result, even if fired under exceptionally favorable circumstances, whereas that which destroyed the United States gunboat "Commodore Jones" in the James River, was one of 1750 lbs. of gunpowder, and by this charge, fired under her, the vessel was simply annihilated. Another advance exhibited during this war is the introduction of an electrical system of ignition. The machines used by the Russians were adapted for mechanical ignition, and were consequently equally dangerous to friend or foe, whereas towards the end of the American civil war, the Confederates arranged some of their submarine mines for ignition by electricity, thus securing safety to their own vessels while in their vicinity without imparing their efficiency for use against an enemy. Since the conclusion of the war the United States Government have improved their systems, and are now said to be building a torpedo boat of a very formidable character for experimental purposes.

Austrian Submarine Mines.

The results arrived at during the civil war in America were so decided, that the investigation of the subject of the use of torpedoes and submarine mines has since become almost general among European nations; and we find them again used by the Austrians for the defence of Venice, Pola and the coasts of the Adriatic in 1866. I am not aware that any opportunity occurred for testing the efficiency of the system employed during this war against an enemy's ship, but the whole was exhibited at Paris in 1867. An examination of this apparatus again shows an advance in the science of submarine mining as compared with that used during the American civil war, for whereas in the Confederate system everything was to a certain extent tentative and hurriedly arranged, here we have working patterns of all the materials and apparatus on a certain system, and capable of being rendered available for any service required, by a simple reproduction of the number of articles necessary according to patterns which, after numerous experiments, had been decided on. The arrangement and construction of the equipment exhibited, shows a considerable amount of ingenuity, and reflects much credit on the designer, Baron Von Ebner, of the Austrian Corps of Imperial Engineers.

The Austrians seem to be very well content with their system of submarine mines; with the exception of one or two minor improvements, it now remains precisely the same as used during the war of 1866. A store, specially adapted to contain the apparatus complete, with electric cables &c., for the defence of the Istrian Coast, has been constructed at Pola, at which port a regular system of instruction is carried on under an officer of the Imperial Engineer Corps.

Austrian offensive Torpedo.

The Austrians have adopted Lupin and Whitehead's torpedo as their offensive weapon. They have at present no outrigger system for attacking purposes, nor do they seem to have turned their attention towards the development of a weapon of that nature.

Prussian Submarine Mines.

Again, during the recent war in 1870 and 1871, between France and Germany, submarine mines were extensively used in the defence of the North German ports against the French fleet. The entrances to the chief harbours and the estuaries of the principal rivers, on the North Sea and Baltic coasts, were defended by a combination of mechanical and electrical submarine mines, and where possible, booms and other passive obstructions. No attempt was made by the French fleet to open a passage through these at any point, and we have therefore had no opportunity of judging how far they would have been effective against a real attack. The moral effect, however, of their existence has been clearly demonstrated by the respect with which they were treated. The Germans consider that any system of simple passive defence on this principle would be immensely improved by the addition of torpedo boats, by which an attack could be made on the vessels of a blockading squadron, they have consequently turned their attention to the construction of boats specially fitted for torpedo purposes. Some of these were made during the war, but were not finished in time to enable them to be used against the enemy.

Prussian Torpedo Boats.

Systems of other European nations.

The French, the Danes, the Swedes, the Italians, and other European nations have also turned their attention to this new class of apparatus for warlike purposes, little or nothing, however, is known of the details of their apparatus, and they have had no opportunity of trying it practically during hostile operations.

Committee on Floating Obstructions appointed.

In this country a committee, composed of Naval, Artillery, and Engineer Officers, an eminent Civil Engineer, and the War Department Chemist, was appointed in 1863, to investigate this subject in combination with that of passive obstructions, and their labours are now concluded. An immense number of experiments have been made under their supervision, with a view to the determination of the details of the apparatus, &c., best suited for the purpose; and many of these experiments were carried on by the officers and men of the Royal Engineers, at Chatham. The result of their investigations was published by the War Office, in the form of a confidential Blue Book in 1868.

Experiments carried on by R. E. Committee.

After the dissolution of the Committee on Floating Obstructions, the investigation of the question of Defence by Submarine Mines was taken up by the Royal Engineer Committee, and a considerable advance was made towards a decision on the details of apparatus required for the effective employment of such a system. Want of money to carry on experiments retarded the operations of this committee considerably, and it was only when war broke out between France and Germany that the importance of a provision for a system of defence of this nature began to be appreciated. In the autumn of 1870, a special committee, called the Torpedo Committee, composed of Naval, and Engineer Officers, and the War Department Chemist, to continue the investigation of

Appointment of

this subject, was appointed, and funds on a more liberal scale were provided for experimental purposes. This committee adopted, with certain improvements, the details of apparatus and general programme as to future experiments, drawn up by their predecessors. Under their auspices patterns of apparatus of all kinds have been decided on and sealed for service, and a commencement has been made by establishing a small reserve of stores of the nature required. The result of the labours of this committee are now, (March 1872), about to be published for the information of officers who would be charged with the duties of supervision of a system of defence of this nature. *Torpedo Committee.*

Instruction in the theory and practice of electricity and its application to the ignition of gunpowder and other explosive agents, for mining purposes, both on shore, under water, and also as required in connection with a system of submarine mines, has for some time been given in the School of Telegraphy, at Chatham. The subject is, however, of such vital importance that it has become necessary to extend the scale of instruction, from the small and makeshift way in which it was formerly taught, to such a system as would be required on actual service; and for this purpose a special school has been established in connection with the School of Military Engineering, at Chatham, for the instruction of Officers and Men of the Royal Engineers in submarine mining operations. This was commenced in the year 1868, and has been gradually extended up to the present time; a floating school has been established, from whence instruction is carried on in mooring, testing, and firing submarine mines, for which purpose a tug steamer, a steam launch, and several boats specially fitted for this service, together with the necessary cases, circuit closers, electric cables, voltaic batteries, sinkers, mooring gear, &c., have been provided. A system of submarine mines has also been placed in position outside Sheerness, in the direction of the Nore, and has been maintained there for upwards of twelve months, for purposes of experiment and instruction. *Course of instruction at Chatham.*

The Officers and Men of the Royal Engineers, instructed in this school, have been employed from time to time by the Board of Trade, in the removal of wrecks by submarine explosions. In this duty they have been very successful, though some of their operations have been carried on under very difficult circumstances, as for example, the wreck of the "Golden Fleece," a large iron steamer laden with coals, sunk off Sully Island in the Bristol Channel; and that of the schooner "Iredes," laden with slates, sunk on the Cant Sand at the mouth of the Thames. The nature of the cargo in these cases rendered the operation of demolition somewhat difficult, and the "Golden Fleece," being a strongly-built iron vessel, sunk in a position where there is a large rise and fall of tide, swift current and discolored water, such as that of the British Channel, in which a diver could not work, presented a *Removal of wrecks by men instructed at Chatham.*

combination of unusual difficulty, which required much ingenuity to overcome.

The 4th Company of the Royal Engineers has been detailed to form the nucleus of a Torpedo Corps, the numbers of which will be gradually increased as men are instructed in the school.

Offensive mines or torpedoes.

These new forms of weapon, for use against ships, may be divided into two classes, offensive, which are called "Torpedoes," and defensive, now known as "Submarine Mines." The first, the offensive class or "Torpedo," falls more particularly to the province of the Navy. It includes every class of device, designed for the active attack of vessels, whether arranged at the end of a spar or boom, in connection with a properly fitted torpedo boat, to be used in ramming an enemy's ship, or to be carried on board ship and thrown out with a view of acting against a vessel in chase, and exploded by electricity or mechanically, when in actual contact with her, or to be used for the attack of a vessel at anchor. To this class also belong drifting torpedoes, or those propelled by any mechanical arrangement through the water, and of such a form as would be applicable for the attack of floating or other obstructions, or of pontoon bridges, &c. Instruction in such appliances is now regularly conducted on board Her Majesty's Gunnery Ships Excellent and Cambridge, and a very good practical book, in connection with this course, has been drawn up by Commander Fisher, R.N., who lately had charge of this duty on board the former vessel. The Officers and Men of the Royal Engineers should understand the mode in which torpedoes, (offensive mines), are employed, especially with reference to the attack and defence of pontoon bridges; and it is desirable that they should be well practised in the demolition, by torpedoes, as well as in the construction of booms and other passive obstructions. As yet, however, nothing has been done towards their instruction in this respect, our attention and time having been devoted to the development of a system of defensive mines. Torpedo boats have however, been designed and are constantly used during the course of instruction given on board Her Majesty's Gunnery Ships, and a short account of the details of such a boat, as well as of the best known forms of outrigger, towing, locomotive and drifting torpedoes, will be given for general information.

To the Naval branch of the service, would seem to appertain the designing and practical use of the apparatus adapted for searching for and carrying off an enemy's mines, and the defence of vessels against mines of every class, whether stationary or drifting.

Defensive mines, or submarine mines.

We now come to the second class of these contrivances, viz., the defensive, or "Submarine Mine," called See-mine (Sea Mine) by the Germans. These fall within the province of the Military branch of the service, and have, in this country, been placed under the charge of the Royal Engineers.

Submarine mines are precisely analogous to the countermines of a land fortress. They seem applicable to almost any circumstances, and may be used with a very great advantage to the defence, in innumerable instances, from that of a first class sea coast fortress, against a first class fleet of iron-clads, to that of a fishing village against a small privateer. This assertion seems to be strongly borne out by the experience we have gained, from the perusal of the accounts of the naval operations, during the late civil war in the United States of America. During that war the iron clad and even wooden vessels of the Federal fleet, frequently silenced and ran past Confederate shore batteries, the latter armed with numerous and well served pieces of heavy calibre, rifled as well as smooth bore. For example, Forts Jackson and St. Philip, defending the entrance to New Orleans, and mounting about 100 heavy guns, with the advantages of numerous shoals and a swift current, failed to stop a squadron of wooden ships, which ran past them after a few days bombardment from their mortar vessels. Again at Vicksburg, after a short bombardment, the Federal fleet ran past the batteries commanding the river, with the loss of only a few men, subsequently passing down again with a similar result. On this occasion there were about 30 guns in the shore batteries against 40 on board the ships, some of the vessels were however iron-clads.

Again at Fort Fisher, at the mouth of Cape Fear River, leading to Wilmington, the Confederate guns were, on two occasions, silenced by those of the Federal iron-clad fleet. These are only a few of the numerous instances in which similar results were obtained, in fact the obstructions and submarine mines of the Confederates gave much more trouble, and caused much more delay and damage to the Federal fleets, than the batteries. Witness the notable example of Charleston, where, though the guns of Fort Sumpter were silenced over and over again, the vessels were kept out for months by the obstructions and submarine mines. Admiral David D. Porter, of the United States Navy, in his very able report on the defensive powers of coast batteries, states: "The running past a battery is a very easy thing, when there is a straight channel and sufficient depth of water; and there is no fort in any of the waters of the North that cannot be safely passed, and (in military phrase) the position turned; and no forts now built can keep out a large fleet unless the channel is obstructed." And again, "Obstructions and Torpedoes are a better defence than our present forts." Such is the deliberate opinion of a very able naval officer, given after an experience of three or four years in the attack of shore batteries of every variety, and what has been done once may no doubt be done again. The use of submarine mines does not, in any way, enable us to dispense with guns and batteries; these are as necessary, if not more so, than ever. Though it cannot be said that

Opinion of Admiral Porter, United States Navy.

shore batteries may not be verv much improved and their defensive powers against shipping greatly increased, taking them gun for gun as against an attacking fleet, there seems to be sufficient data to show that the defensive power of the very best fort that can be built, will be much increased by a judicious arrangement of obstructions or submarine mines, or a combination of both.

The effect of submarine mines in improving the defences of the North German ports, was strongly exemplified during the recent struggle with France, and there is no doubt that in all future wars they will play a very important part.

Defence of a first-class fortress, as Portsmouth

If used in the defence of a first-class fortress, such as Portsmouth for example, they should be so arranged as to be covered by the guns of the forts and floating batteries, so that while acting as outworks to these latter, they would be protected by them from disturbance by the boats of a hostile fleet.

Defence of a mercantile harbour, as Liverpool.

Another case, in which submarine mines could be effectively used, is that of a great mercantile harbour defended by forts carrying a few heavy guns, as Liverpool for example. Here we have a few guns in position, which might be silenced by a sufficiently powerful hostile fleet; but if a judicious arrangement of submarine mines were added to these, placed in such a position as to be covered by the guns, and by those of such vessels of war as might be at hand, and at the same time advanced sufficiently far to prevent the guns of an enemy's vessels from reaching the shipping in the port, the position, as regards the defence would be immensely improved.

In all cases, by a very simple arrangement, to be hereafter described, the channel could be made perfectly safe to friendly vessels, which could run in and out at pleasure, while it could, at any moment, be made instantly dangerous should an enemy attempt to follow.

Useful in an undefended harbour, as Belfast.

A third case, in which submarine mines could be used with advantage, is that of the estuary of a river, leading to a mercantile harbour and not necessarily defended by forts of any sort, as for example Belfast. This important port is situated a considerable distance up an arm of the sea, on a river, and is, or used to be, so nearly undefended by guns that, for the sake of example, they need not be considered as an item in its defence. Under present circumstances Belfast would be open to the attack of a comparatively small fleet of hostile vessels, and its destruction would be a very serious blow in a commercial point of view. If a well arranged system of submarine mines, however, were placed in the estuary of the river, with one or two gunboats or a floating battery, to prevent boats from searching for them, the place would be quite safe from any sudden attack and would be capable of holding out against an enemy's squadron, with a fair prospect of success, till relieved. Here again the mines must be placed at such a distance as to keep hostile vessels where their fire would

be ineffective against the shipping and town. Should no gun-boats or floating batteries be at hand, a few guns in an earthwork to cover the mines would be advisable, but even without them a defence, on this system, might still be carried on, and it would only be necessary to put down a greater number of mines, so that one might occasionally be fired at a boat engaged in grappling for them, as a deterrent. As a rule they should not however be thrown away at small boats, but reserved for more worthy objects.

Defence of small harbours, as Whitby.

Another instance in which submarine mines might be advantageously employed, without any combination of protecting guns, is that of a harbour close upon the sea, which could be easily reached by an enemy's guns. Such a place as Whitby for example, which affords a port of considerable importance to the coasting and fishing trade. A few submarine mines laid 4,000 or 5,000 yards to seaward from this place would, by the fact of their existence, deter an enemy's vessels from approaching, as the advantage to be gained would not be worth the danger incurred, while a harbour of refuge would be secured to friendly ships. In such a position as this, it might not be practicable to use them at night or in a fog, unless some means were adopted for signalling the approach of an enemy.

Defence of town open to sea, as Brighton.

Again, they might be used for the protection of such a place as Brighton, where no harbour exists, but which is quite open and assailable from the sea, and any attempt to defend which with guns, could only end in its destruction by bombardment. In such a case a few submarine mines, placed at a distance of a few thousand yards to seaward, would exercise a salutary deterrent effect. These mines should also be rendered inactive at night or in a fog to prevent accidents unless some means of signalling were adopted.

Defence of an open beach.

Another case in which they might be usefully employed, is that of a flat open beach, on which an invading force might be landed with facility, as for example Sandown bay in the Isle of Wight. At this point a strong fort has been built, in connection with the defences of Portsmouth, to prevent such a contingency. A few submarine mines judiciously placed in such a position, and covered by the guns of the fort would, no doubt, vastly increase the chance of a successful defence, and act as a deterrent against any attempt to land; and probably in many similar positions a smaller fort, only carrying a sufficient number of guns to protect the submarine mines, would answer the purpose.

Protection of an inferior fleet.

One use to which submarine mines may be applied must not be forgotten; it is that, by their means, an inferior fleet has the power of placing an impassable barrier between itself and an enemy, reserving however the power of passing out when required and of retreating to a strong position at any moment, should it be unable to cope with its adversaries. A fleet of merchant vessels might also, so to speak, be similarly intrenched.

Defence by submarine mines specially applicable to Great Britain and Ireland and our colonies.

The above are a few of the cases in which it seems that submarine mines could be used with effect, and there are no doubt many others which might be enumerated, and even a cursory consideration of the advantages to be derived, gives an impression of their importance, to a country with such a great length of coast as that of Great Britain, Ireland, and our colonies to be defended. They seem especially adapted for the defence of Colonial ports, many of which under present circumstances, would be at the mercy of a comparatively small squadron of an enemy's vessels or even a single iron clad, which could probably run past or silence the few guns defending them, and bombard or lay the port under contribution. The presence of a few well placed submarine mines would, however, completely alter the state of affairs and render a different mode of attack necessary. There would then be no alternative but to begin the tedious and dangerous operation of clearing the channel, or to land and attempt to capture the place, without the aid of the ships, in which latter case the defenders would stand a fair chance of success, in dealing with the attacking force, which would then probably be acting at a disadvantage or at best on equal terms only. Another point gained would be, that each port so defended, would become a harbour of refuge, into which a friendly vessel could pass freely, but which would be effectually barred against an enemy in pursuit. In case of war it would be no uncommon thing for a friendly vessel to be chased into one of our harbours, as for example Melbourne: in such a case a system of submarine mines would be invaluable. Finally, submarine mines may be used in combination with, or without, passive obstructions of every variety.

Moral effect considerable

The experience of the late civil war in the United States, as well as that of the more recent war between France and Germany, teaches us, that the moral effect of a system of defence by submarine mines would be very great. Men will face a known danger readily, but it is not so with a hidden one. The result therefore would be a considerable increase of caution in the mode of approach over places where submarine mines were supposed to be lodged, with a corresponding delay and loss of time in the attack, which, in many cases, would enable the defenders to hold out till relieved. Suppose, for example, such a place as Liverpool were attacked by an enemy's squadron:—in its present state, protected as it is by a few moderately strong forts, past which iron clad vessels might run without serious loss, it would be at the mercy of an enemy. If a judicious arrangement of submarine mines were, however, added to the present guns, the same squadron could not get in, in this off-hand way, and would probably not think it worth while to incur any delay, in attempting to force a passage as, by the aid of the electric telegraph, it is more than probable that a strong relieving squadron would be off the port before many days had passed.

There is one very important consideration, with reference to this question, viz.: That the cost of a system of defence, by submarine mines, is comparative trifling. A channel 100 yards wide might in this way, be defended at an outlay not exceeding that incurred in the purchase of half a dozen heavy rifled guns, to say nothing of the ammunition required for a modern artillery armament, the cost of which is considerable, or of the works in which the guns are placed.

Cost comparatively small.

Again the materials required in the construction of the apparatus are all articles of commerce easily procurable; the submarine Cables, which would perhaps be the most difficult part of the equipment to obtain in out of the way places, may always be kept in store and laid down when required; and finally,. a system of defence, by submarine mines, can be worked by a comparatively small number of men. All these are important points in connection with a subject, which seems capable of such universal application, especially when viewed with reference to the defence of our numerous and distant Colonial possessions.

Material easily obtainable.

The advantage to be derived from the use of submarine mines is a very considerable increase in defensive power. One important point is, that of setting free our fleet, to act at sea against that of an enemy; as a very much smaller naval force would be required for harbour defence, and it might consequently be concentrated and used to greater advantage in active operations. Another is the addition, to a very considerable extent, of the defensive powers of our coast batteries and fortresses; that addition being obtainable at a comparatively small cost and with a comparatively small number of specially trained men. A third is the acquisition of a power to defend places, which have hitherto been deemed indefensible. A fourth is the power of converting every British Harbour into a port of refuge, accessible at any moment to friendly vessels, but absolutely impassable to an enemy.

Advantage, great increase in defensive power.

CHAPTER II.

General Principles.

Nature of Submarine Mines.

We will now proceed to consider, in general terms, the nature of submarine mines. They may be briefly described as charges of gunpowder, gun cotton, or other explosive agents, of various sizes up to 2000lbs. of gunpowder, or its equivalent, enclosed in water tight cases of iron or other material, and placed under water at such depths that, by their explosion, they may sink, or seriously damage a vessel passing in their vicinity. They may be classed under two heads, viz.: Mechanical, those which depend for the explosion of the charge on mechanical means, such as the simple percussion of a vessel coming in contact with them; and Electrical, those which are fired by electrical agency, either by the vessel herself closing the circuit, or at will from the shore. The details of the arrangements in both these systems shall be considered hereafter.

Mechanical Submarine Mines.

The former class, or mechanical mines, should only be employed when the circumstances of the case are favourable to their use. When once placed in a channel it becomes equally impassable to friend and foe: they are therefore only applicable under certain conditions, as, for example, where it becomes necessary to block up a channel completely, that is to say to render it altogether impassable till the mines have been again removed; for instance, to enclose an enemy's fleet, and thus limit its sphere of action, or under any similar circumstances. They could be very usefully employed on a flat beach, nearly dry at low water, to cover the flanks of electrical mines, defending the navigable channel; in such a case they could be placed in position or removed at low water in comparative security, and the number of electrical cables, &c., required for the whole system of defence might, by such an arrangement, be reduced.

Disadvantages.

They would not be applicable to the formation of harbours of refuge, as previously alluded to, where merchant ships could run in to avoid an enemy. It would be absolutely necessary to make some arrangement, so that they might be exploded at will, as the most effectual way of gettting rid of them, when it became necessary to clear the channel, as the process of removal in the ordi-

nary way by boats would be far too dangerous an operation to undertake : in fact, it would be difficult, nay, almost impossible, to get men to do it. Several serious accidents occurred in placing the mechanical mines, which were extensively used by the Germans during the recent war with France, in position : and many more during the dangerous process of clearing the channels after the war was over, causing the loss of valuable lives. This became so serious, that latterly the process of removal was given up, and means were adopted for exploding them as the safest way of getting rid of them. One mode adopted was to fire at them with a rifle, to penetrate the case and swamp the charge.

Advantages.

They possess the advantages of being capable of being kept in store and made ready for use at short notice; they require no knowledge of electricity in their preparation and management; and they might be used, in certain cases, with advantage where electrical submarine mines are not obtainable.

Electrical Submarine Mines.

The second class of submarine mines are those to be fired by electrical agency. These admit of a very much larger field for their employment. They may be fired either at will, (the position of a vessel with regard to them being determined by the judgement of an observer, who himself closes the electrical circuit, so that the charge may be exploded at the right moment), or the vessel herself may be made to complete the circuit, causing an electrical current to pass and fire the charge.

Disadvantages.

The disadvantages of electrical submarine mines, as compared with those fired by mechanical means, are the multiplicity of wires required, and the necessity of having a certain number of specially trained men; but as the number of such men would be comparatively small, this latter point is not of so much importance.

Advantages.

The advantages of electrical submarine mines are, that they are always absolutely under the control of the observer in charge of them. By simply detaching the voltaic battery used to fire them, which may be done by the removal of a connecting plug, they become perfectly harmless, and friendly vessels may pass over them with safety, which is not the case with those arranged for mechanical ignition. Again they can be rendered active at a moment's notice, by simply inserting the plug connecting the voltaic firing battery.

A safeguard against surprise.

One great advantage arising from the use of submarine mines is, that no vessel could pass through a channel, protected in this way, at night or in a fog, without affording the means of indicating her presence, and thus they are a great safe-guard against an attack by surprise. In this respect the electrical system has a very great advantage. Mechanical mines would no doubt act and be fired when struck, but the electrical need not necessarily be fired, and are capable of being arranged, in a very simple manner, so that without being exploded, they may indicate that a vessel has passed over the charge. Except in extraordinary

cases, it would not be advisable to throw away a mine in damaging or sinking a small boat, as a gap would thus be made in the line, giving a safe passage to more formidable vessels; taking this into consideration, therefore, there is again an advantage in favour of the electrical system, for the mechanical submarine mine must act, whatever be the size of the vessel striking it, whereas the electrical one may be reserved at pleasure for an object worthy of the expenditure of the charge.

Fresh mines can be added. Another advantage of the electrical system is, that when a charge has been fired, or become ineffective from any cause, another can be laid down in its place, and the gap thus formed in a line made good, unless an enemy is in such a position as to be able to prevent it. To perform such an operation with safety it would only be necessary to render the neighbouring mines, for the time being, inactive, so that a boat might pass over them in safety to the point required. Should a break occur in the mechanical system, by the explosion or destruction of a charge, there it must remain; for it would be impossible to get men to risk the chances of being blown up in replacing it by another, and, even if volunteers for such a dangerous service could be procured, the chance of creating a greater opening, by the accidental explosion of other charges, would be so considerable that it would not be prudent to attempt it.

Can be tested electrically. Perhaps the most important advantage of the electrical system is the power of testing electrically, without going near it, the condition of each separate charge at any moment after submersion, and of ascertaining with almost absolute certainty whether it can be fired or not. If, in the electrical system, the charges were grappled by an enemy and carried away, the disconnection of any particular charge or charges would be at once made known to the defenders, by the electrical tests employed. No such power exists in connection with the mechanical system.

Can be raised for examination. Again in the electrical system, a charge may be taken up at any time for examination with perfect safety, whereas it would be very dangerous to attempt such an operation in the mechanical system.

Improvements in safety of Mechanical Mines. Some important improvements in their construction have recently been suggested by Captain Harding Steward, R.E., F. Abel, Esq. F.R.S., chemist of the War Department, and Quartermaster-Sergeant Mathieson, R.E., which would make loaded mechanical mines very much safer to handle; but even with the additions proposed, they would never be as easily and safely manipulated as mines on the electrical system. This question of providing for the safe handling of loaded mechanical mines, with the fuzes attached, is a very important one, and should not be lost sight of. Experiments are required, with a view to the accomplishment of such a very desirable result. A moderate amount of safety is essential to their practical working.

Danger in submerging Mechanical Mines.

During the recent war with Russia many of their infernal machines, as they were called, failed to explode on contact with the vessels of the blockading squadron; this is accounted for by the fact, that the men employed to place them in the water were afraid to remove the guards and contrivances arranged to make them safe to handle. This was found to be the case in some of the submarine mines picked up by the boats of the blockading squadron, and, with such very dangerous machines, it would no doubt occasionally occur. The suggestions above referred to would, to some extent, obviate the chance of such an occurrence, by reducing the danger to be incurred during the process of submersion very materially.

We will now proceed to consider the conditions under which submarine mines may most advantageously be made to offer the greatest possible obstacle to the advance of an enemy's vessels.

Project for the Defence of Venice by Submarine Mines and Passive Obstructions

In an Austrian work, somewhat corresponding to the Corps Papers of the Royal Engineers, entitled "Mittheilungen über Gegenstände der Ingenieur-und kriegs-Wissenschaften Herausgegeben, Vom Kais Kön génie-comité Jahrgang, 1867," the following description is given of the method proposed for fortifying the entrance to the port of Venice, during the war in 1866, (which arrangement was not however carried out). Three booms or passive obstructions were proposed, the outer one, that next the enemy, to be of light construction, the inner two to be as strong as they could possibly be made; between the two heavy booms a double row, in échelon, of submarine mines to be fired by the contact of a vessel, were to have been placed, and inside the inner heavy boom, what are termed "mines of observation" were to have been arranged; these latter were designed to be fired at will, and were intended to come into play had any vessel of the enemy's fleet succeeded in passing through the obstructions above described. The light outside boom was probably intended as a protection against drifting torpedoes or ships' boats which might be sent to attempt to damage the heavier booms and render them less resistant to the passage of large vessels. The whole was covered by the fire of the guns of the place.

Defence of Kiel during War in 1870-71.

The arrangements made for the defence of Kiel, by submarine mines and obstructions, during the recent war between France and Germany, give a very good idea of the nature of the means employed by the Germans in all their ports and harbours. They were situated about a mile beyond the batteries at Friedrichsort, towards the sea, and arranged as follows:—Outside was an obstruction of fishing nets, immediately followed by one of Manilla rope, through these two a clear passage was left in the centre as a ship channel: within the obstructions were placed the submarine mines, mechanical mines on the flanks, and electrical mines, to be fired at will by the aid of Siemen's range finding apparatus, in the ship channel in the centre. Within the mines came a

number of heavy timber rafts, moored right across the channel, and connected together by a heavy chain cable. A ship channel was provided in the centre of these, by making a certain number of them moveable at pleasure, so as to give an opening sufficient for the passage of vessels. Within the row of rafts was a row of coasting vessels, also moored completely across the channel, and connected together by a heavy chain cable. A ship passage was provided through these by making some of them moveable, as in the case of the rafts. The whole system was covered by the guns of several formidable batteries on both sides of the bay. The harbour of Kiel, being landlocked, is a very favourable place for a system of defence by submarine mines and obstructions; and the arrangements here appear to have been more complete than in the case of other harbours and estuaries of rivers defended. Greater difficulty was experienced at certain points along the coast. Where the defences were exposed to the wash of the open sea, the net and rope obstructions were always seriously damaged by stormy weather, and in every case modifications had to be adopted, consequent upon the peculiar conditions to be fulfilled in carrying out a system of defence of this nature. Kiel, being situated at the head of a long narrow arm of the sea, is very favourably placed for a system of defence by this means. There is but little rise and fall of the tide, and the town and dockyard, having been several miles within the line of mines and obstructions, would have been quite safe from bombardment by the enemy's ships, unless those ships had forced their way through the defences provided.

Von Scheliha's Observations on Obstructions & Submarine Mines.

Colonel Von Scheliha, of the Engineers of the late Confederate States, gives in his *Treatise on Coast Defences*, published in 1868, an account of several forms of submarine mines and torpedoes used during the late war, and of their effect in certain cases. He is of opinion that submarine mines alone are not a sufficient obstruction against an attacking fleet; that they should always be combined with passive obstructions of the heaviest character possible, and be well covered by guns, to prevent a search being made for them by the enemy.

To Close a Channel completely.

In shallow waters he proposes to use passive obstructions of the heaviest nature, resting on the ground. When the water is of such a depth as to preclude the use of passive obstructions, resting on the bottom, except at an enormous outlay of time, money, materials and labour, he proposes to use very heavy floating obstructions securely moored; and he would use his submarine mines in places, where in consequence of the depth of water or the strength of the current, ground or floating obstructions, would be either very difficult to make and keep in position, or would be altogether impracticable.

To Preserve a Free & ye Defensive Passage.

Where a free channel is required, which may however be closed at will against an enemy, he proposes to use electricity as the exploding agent.

Von Scheliha's experience chiefly gained with Mechanical Mines.

His experience has been gained chiefly with self-acting mechanical mines, and he gives much interesting information on their construction, and advantages and defects, under various circumstances. Electrical exploding arrangements were not much used by the Confederates during the war, but they used mechanical self-acting mines very extensively, both on shore in covering defensive works, and under water for attacking as well as defensive purposes. Since his book was written, electrical and other improvements have been made in the construction and arrangement of submarine mines, and in their present form there is no doubt they may be used with advantage in many places, without any combination of passive obstructions. These latter would no doubt prove most useful in rivers and narrow channels, where the force of the current and other conditions may be favourable to their employment, but there are many places, an open roadstead, such as Spithead for example, where it would be extremely difficult, if not impossible, to employ passive obstructions, but where there is every probability that submarine mines could be effectively used.

General Rules.

The following general rules must be borne in mind with reference to any system of submarine mines—

1st. They may be used in combination with floating and grounded obstructions, or without them.

2nd. They should be placed in such positions that their explosion shall not injure any passive obstructions combined with them, or destroy adjoining mines, or their electric cables, and mooring gear.

3rd. At least two, and where practicable, more, rows of mines should be arranged in échelon across a channel to be defended.

In deep water it is more necessary to employ several lines of mines than in shallow, because, in the latter case, a vessel sunk by a mine would herself offer an impediment to others following, but in deep water the explosion of a mine leaves a gap, through which there is a safe passage, as far as the line of mines in which it occurs is concerned.

4th. As a general rule electrical submarine mines should be placed in the channels through which large vessels only can pass; the shallower portions being, in all cases where such a course is practicable, rendered impassable, by passive obstructions resting on the bottom or mechanical mines.

5th. Submarine mines should be placed in the narrowest parts of a channel. The advantages of such positions are evident, as a smaller number would answer the purpose.

6th. Where the depth of water and other circumstances admit of it, a submarine mine should always rest on the bottom;

under such circumstances many of the complications originated in mooring arrangements are avoided; its position is more easily defined, and it is not so easily displaced by accident, or discovered, and destroyed by an enemy.

7th. No indication of their position should, if possible, be allowed to appear on the surface of the water. Under certain conditions it may be impracticable to conceal them altogether, as for example, where there is a large rise and fall of the tide; under such circumstances the smallest possible indication of their position must be allowed.

8th. Where, from the depth of the water, the charges cannot be placed on the bottom, they should be so moored as to float from 15 to 70 feet, according to the size of charge employed, below the surface. In places where there is a considerable rise and fall of the tide special arrangements would be necessary.

9th. The places in which the voltaic batteries and instruments connected with the ignition of electrical submarine mines are situated, should be in those portions of the defensive works which are likely to be held longest, so that a command may be kept over the mines to the latest possible moment in the defence.

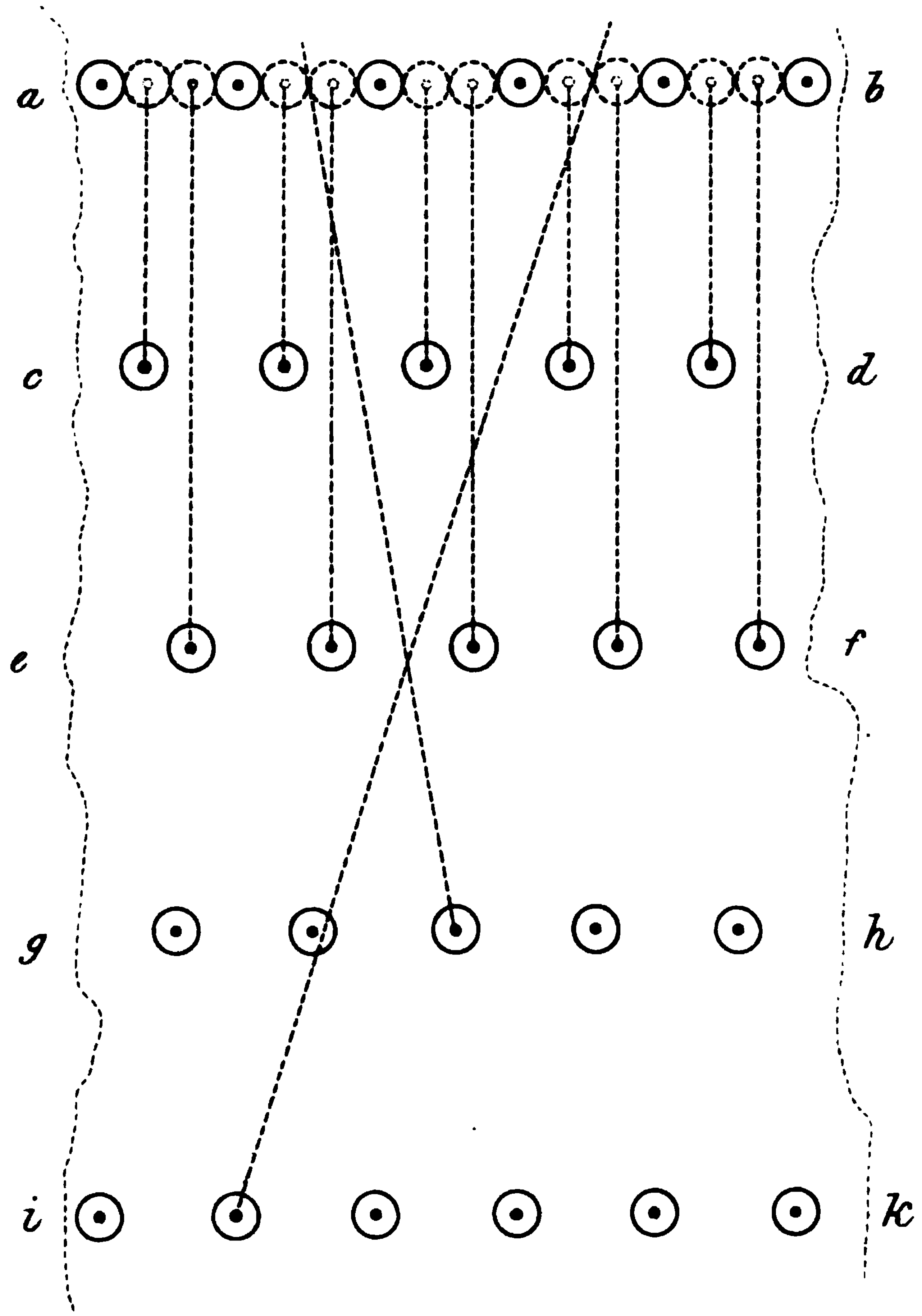
10th. Great care should be taken to lay the electric cables in such positions as to render their discovery by an enemy as difficult as possible. The Confederates used many devices to conceal the conducting wires of their mines, and amongst others, that of carrying them in by circuitous routes and burying them underground, to discover which the Federals dug trenches across the courses which they would be most likely to take.

11th. The position of the mines should be well covered by the fire of the guns of the fort or floating batteries of the place to be defended, to prevent their disturbance by boats.

12th. Submarine mines should not be thrown away by firing at small boats, except under very exceptional circumstances, but should be reserved for larger vessels.

General Principles of Defence of a Channel

The object to be attained in arranging any system of mines for the defence of a channel is to place them in such a position that a vessel in passing along that channel must, at some one moment, whatever course she may take, be in such position as to come within the radius of destructive effect of one of the mines during her progress. In order to attain this end, it would only seem necessary to place the mines so that the circles described by their radii of destructive effect may at least touch each other. Theoretically this is no doubt the case, but practically such a system presents difficulties which would prevent its being worked out, and moreover has certain disadvantages inseparably connected with it. Among the practical difficulties is the danger of entanglement between the mooring cables of adjacent mines, or their circuit closers, especially when there is any rise or fall of the tide; when mines are very close to each other it is practically



Lithographed at the S. M. E. Chatham.

B. Butler, Corpl. R. E.

impossible to prevent entanglements of this nature, even with the most perfect mooring arrangements. Again, when mines are very close to each other, the explosion of one is very likely to injure its neighbours, or, when an electrical system of explosion is adopted, to disturb the circuit closers, electric cables, &c., connected with them; and the difficulty of paying out the electric cables and arranging the gear in connection therewith, as well as the grappling for and raising a mine for examination, would be much increased by this very close and precise formation, even if it were in other respects practicable. In fact, a certain amount of latitude, so to speak, is absolutely necessary, in order to simplify the operation of mooring, and keep the mines safe from the explosion of those adjoining them.

Disadvantages of a Single Line.

Among the positive disadvantages of such an arrangement is the fact that if a breach were once made in such a line, that breach would, till repaired, afford a safe passage to an enemy's ship. Again, an enemy having once ascertained the position of such a line, could easily define the limits of the area of the danger, and take the necessary measures to avoid it. These disadvantages may be overcome by spreading the mines over a certain area, so that while reducing the difficulties of placing in position and preserving for the defenders a certain formation, which secures to them the power of identification, with the more precise information and delicate instruments within their reach, the difficulties to an enemy of obtaining a definite knowledge of the area defended may be proportionately increased.

Simple Distribution of Mines for Defence of Channel.

The simplest method in which a system of mines can be arranged for the defence of a channel, is shewn in *Plate* I., which also illustrates the general principles on which they should be distributed in all cases. In this figure *a b* represents the theoretical line required to defend the channel, and it is only necessary to move every second mine back to the line *c d*, and every third to the line *e f*, to secure the objects required. A fourth line, *g h*, or even a fifth, *i k*, may be added with advantage, taking care that these last shall cover the intervals left between those in advance of them, in such a way that a vessel passing in obliquely through the intervals of the first three lines, may come in contact with a mine on the fourth or fifth. An arrangement in lines is convenient, as giving the greatest facilities for firing at will by the method of cross bearings, or for finding the position of a mine in the event of its becoming necessary to raise it for examination. If the lines are so placed as all to converge on a single distant point, say a mile or more distant, the combination is much simplified, while the actual position of each mine is thereby so little altered that it may without difficulty be made to fulfil all the necessary conditions. The rules regulating the intervals to be left between adjacent charges in a line of mines, as well as between the lines themselves, shall be discussed hereafter.

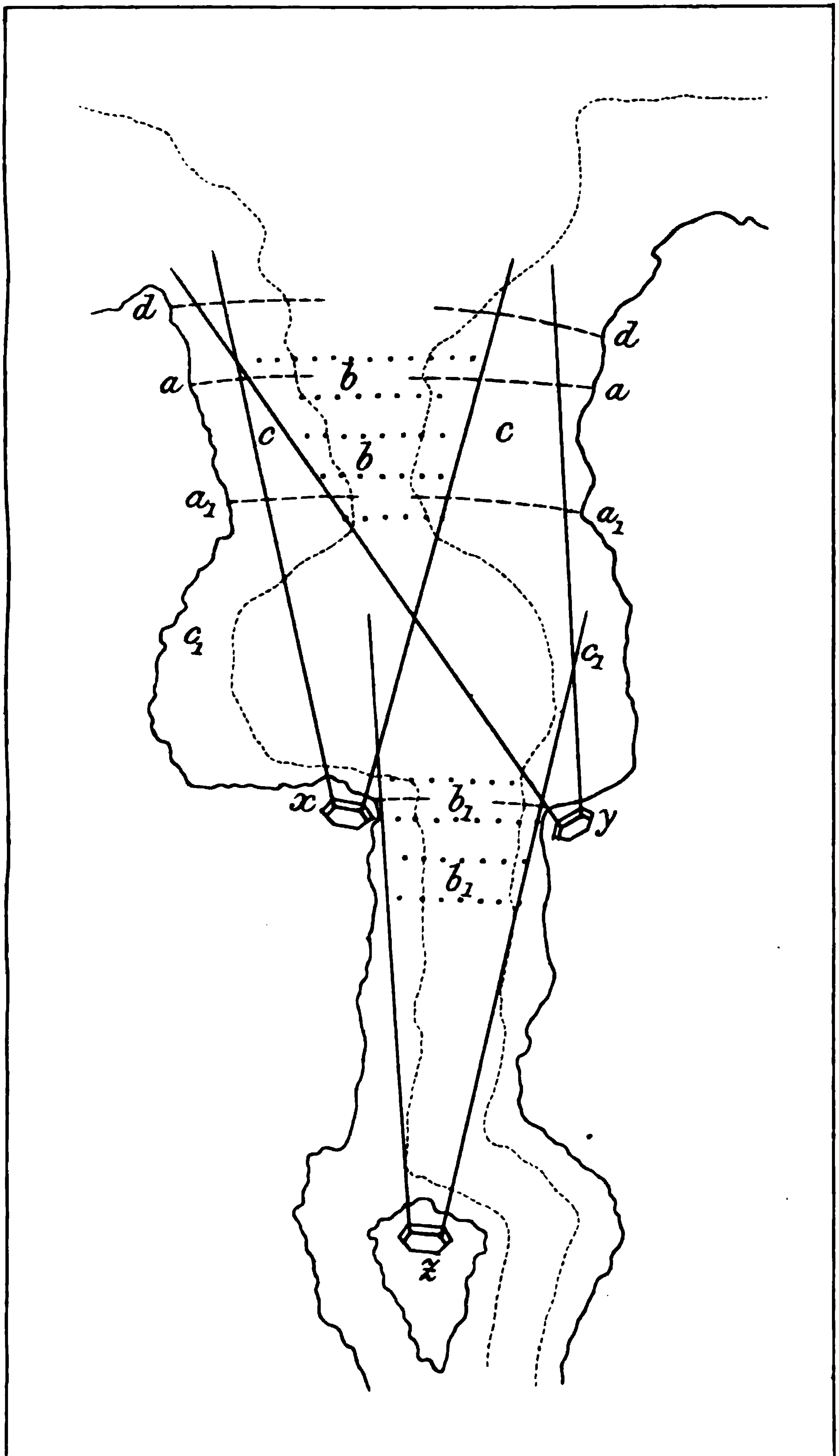
Disadvantages of an Arrangement in Lines.

The arrangement of a system of submarine mines in lines possesses certain disadvantages, even when they are thus distributed over a given space. The front and rear being in a line formation at once defines the dangerous area, which an enemy would avoid if he once obtained information as to its position. To obviate this, it is only necessary to place a few mines at irregular intervals, in front and rear of the main body, which latter might for the sake of convenience still be retained in the line formation.

Defence of a Channel by a Combination of Submarine Mines and Passive Obstructions.

Let us now suppose a case in which it would, from the depth of water, strength of currents and other conditions, be practicable and desirable to institute a combined system of defence by passive obstructions and submarine mines, as for example, an estuary of a river, such as that represented in *Plate* II., defended by three batteries, x, y, and z.

The most eligible points, which would be those where the channel is narrowest, or bends where facilities exist for enfilading the lines of obstruction by guns, and which would offer advantages for fixing the positions of the submerged mines very accurately by intersections, or cross bearings as they are sometimes called, and other places offering local advantages, having been selected, obstructions and booms might be formed, as at a, a, a_1 a_1 in which openings would be left, in the ship channel, to allow of free ingress and egress. Across these openings it would be necessary to place several lines of submarine mines, b, b, b_1 b_1 arranged to be fired by electricity, extending so far on each side of the deep or ship channel as completely to cover it, and well protected by the fire of the forts x, y, and z; and a light boom, or obstruction formed of fishing nets and Manilla rope d d, as used by the Germans, might be advantageously placed in advance, to cover the whole system from an attack by drifting torpedoes or boats. The spaces c c, c_1 c_1 are supposed to be covered by a few feet of water only at low water, and in them mechanical submarine mines would be placed. The whole would be protected by the fire of the forts, and by guard boats provided with proper apparatus for day and night signalling. The whole of the electric cables in connection with the mines should be carried into the safest available position, if possible into the fort z. The necessity for placing the testing room, that into which the electric cables of any system of submarine mines are carried, and from whence the whole system would be controlled, in a safe place is very great: on it depends the efficiency of the whole. It would not be desirable, for example, to carry the electric cables of the group b_1 b_1 into either of the forts x or y, however conveniently they may be situated as regards distance, unless such an arrangement could not be avoided: they should be carried into the fort z, so that in the event of the forts x and y being lost, the space between them, covered by the group of mines, would still remain as impassable as ever to the attacking ships. The electric cables



Lithographed at the S. M. E. Chatham.

B. Butler, Corp! R. E.

in connection with the advanced line of mines, *b b*, might perhaps be carried into the forts *x* and *y*, if the distance were too great to admit of their being carried into the fort *z*; but those of the group b_1 b_1 should most certainly be carried into the fort *z*.

Defence of an Open Roadstead without Passive Obstructions.

In the case of an open roadstead, where the depth of water is so great that passive obstructions could not be conveniently employed, and there is a broad navigable space of water to be defended, the best general plan to adopt would be to moor buoyant, electro-self-acting submarine mines, of the largest size and fitted with circuit closers, in the principal ship channels. The line formation, described in p. 19, and shown in *Plate* I., should he adopted for the general mass of the mines, but in addition to the main body thus formed, there should be a large number of mines irregularly placed in advance and a few in rear of the line formation. Where the conformation of the adjoining shore is convenient, and the distances admit, as many as possible of the mines in the main body should be arranged for the alternative mode of firing at will by cross bearings. The flanks of the systems in the main channels, where the depth of water is insufficient to admit of the passage of large ironclads, but over which gunboats or smaller vessels might still pass, should be defended by 100lb. electro-contact mines: while those portions nearer in shore, where there would be a still smaller depth of water, should be studded with mechanical mines.

The whole system should be well covered by the guns of the forts and batteries defending the roadstead, or by gunboats and floating batteries provided for the purpose, and they should be well patrolled by guard boats, especially at night or in a fog. The precautions already alluded to, for the safety of the testing rooms and electric cables, should be observed in this, as in the case already described, that is to say, the testing rooms should be placed in the most defensible positions, and the electric cables carried in where least likely to be discovered by an enemy or injured by his fire.

So much depends upon local circumstances, such as the nature of the channel or roadstead to be defended, the probable means of attack at the disposal of an enemy, the draft of water of the vessels of a hostile fleet, &c., that a great deal must be left to the discretion of the officer commanding the defence, and the above must not be considered as stereotyped plans which should never be departed from. They are only intended to convey a general idea of the arrangements necessary to meet the objects in view, which would require much modification to suit the specialities of any particular case.

CHAPTER III.

Explosives.

We now come to the consideration of the nature of the explosive, with which a submarine mine can be most effectively charged.

Explosive Agents.

Several agents have been suggested for this purpose, including gunpowder, (of large and fine grain), compressed gun-cotton, (fired with an ordinary and with a detonating fuze), nitro-glycerine, dynamite, Schultz' powder, dualine, and glyoxyline, (a combination of gun-cotton and nitro-glycerine, invented by F. Abel, Esq., F.R.S., War Department Chemist, &c.)

Gunpowder.

Gunpowder is probably the oldest and best known explosive agent that we possess. Its effects, when fired in earth, rock, and masonry, have been determined with great accuracy, but we have still much to learn concerning it, when the surrounding substance is water. During the late civil war in America, the Confederates gave the preference to fine grain or rifle powder, under the supposition that it produced a better result for submarine purposes. An experiment, tried in a well in Pensylvania, seems to bear out this idea. Captain Harding Steward, in his *Notes on Submarine Mines*, gives the following description of the result obstained on that occasion:—"50lbs. of rifle powder sent up a column of water 250ft. high, while with the same charge of coarse grain powder, a column of similar thickness was only driven 70ft. high, and the water was very much discoloured, proving the non-ignition of part of the charge."

The French seem to have got hold of the same idea; in some experiments, recently carried on, they have been trying several varieties of gunpowder, especially manufactured with a view to obtain more rapid ignition.

The Austrians have adopted fine grain powder, in charges of 161 kilogrammes or 396·6lbs., in some of their most approved forms of apparatus.

A strong case essential when gunpowder is used.

It is probable, however, that when gunpowder is used, the strength of case is of more importance than the consideration as to whether coarse or fine grain powder should be employed. A case of sufficient strength to secure a proper development of the explosive force of the charge, would be likely to produce a greater

increase in that force, than would result from a change in the form of powder of which the charge is composed. The experiments made by the Floating Obstruction Committee, seem to prove this to be the fact.

Gun-Cotton.

Gun-cotton is the invention of the German Professor Schönbein, and was originally manufactured in a soft fibrous form, or sometimes as thread or rope. In this form it presented serious disadvantages as regards its practical application, partly on account of its bulky nature and of the necessity for its enclosure in very strong cases; great difficulties were also experienced in manufacturing it of uniform strength, and it was found almost impossible to rid it of certain impurities which, if remaining in the fibre, had a tendency to decompose, thereby developing chemical change in the mass, accompanied by the liberation of heat, which might after a time bring about a spontaneous explosion. The Austrians, who made many experiments on gun-cotton in its fibrous form and used it at first for their submarine mines, have given it up in consequence of the defects above enumerated. An important improvement in manufacture has been made in this explosive by F. Abel, Esq., F.R.S., War Department Chemist, who has elaborated the process under which it is now made in the form of compressed gun-cotton.

Compressed Gun-cotton.

A great number of experiments have been recently made with this substance, fired with an ordinary as well as with a detonating fuze, from which its effects, as compared with those of proportionate charges of gunpowder, have been determined with considerable accuracy. The results obtained from these shew a superiority for gun-cotton over gunpowder for submarine work; its ignition, at all times more rapid than that of gunpowder, is, when fired with a detonating fuze, immensely quickened, and the damaging effect of its explosion is much increased, both of which properties are in its favour.

Increased effect of explosion by a detonating fuze.

The action of a detonating fuze, in developing the explosive force of gun-cotton, nitro-glycerine, and analogous substances, is very remarkable, and this effect extends to gunpowder, and probably to all explosives. Experiments tried at Chatham and elsewhere, have clearly demonstrated that gun-cotton may be made to exert its full force, when only confined in a weak case or bag, or even when exposed in the air, by being fired through the agency of a sudden and sharp concussion, such as that produced by the explosion of a confined charge of fulminate of mercury. The same effect holds good, though in a minor degree, in the case of ordinary gunpowder. Some recent experiments, at Chatham, have proved that more work can be got out of a confined charge of gunpowder fired by a detonating fuze, than if exploded in the ordinary way, under corresponding circumstances.

Abel's Improvements in the manu-

Mr. Abel has identified himself with the advancement of the gun-cotton question, and great credit is due to him for the light he has thrown upon that question by long and patient experimen-

facture of Gun-cotton. tal research. Still greater credit is due to him for having discovered and perfected a method of treating gun-cotton, whereby it is rendered non-explosive when burned in the air, but in which the full energy is developed when fired in a close chamber, or with a detonating fuze. The method consists in reducing the gun-cotton fibre to a fine state of division or pulp, as in the process of paper making, and in converting this pulp into solid masses, of any suitable form or density, under a pressure of about 6 tons to the square inch. This was the method of manufacture, carried out by Messrs. Prentice, at their works at Stowmarket, before the recent disastrous explosion, and it is about to be introduced into the Government establishment, now being created for the manufacture of gun-cotton, at Waltham Abbey. To the pulping is mainly due the safety attained, as it ensures uniformity in washing, whereby the cotton is thoroughly freed from all acid, and thus every chance of spontaneous combustion is removed. The compression causes combustion to proceed slowly in the open air, owing to the condensed condition of the fibres, which, in the loose state of cotton or rope, burn very rapidly. The gun-cotton is compressed into cylindrical or any other convenient forms, and a density equal to that of powder is given to it, whereby its portability and the explosive force of a given volume are greatly increased. The principle of thus combining safety with force, in a highly condensed form, has produced very valuable results.

Spontaneous Explosion of Gun-cotton at Stowmarket.

The late melancholy accident at Stowmarket threw doubt, for a time, on the stability and safety of compressed gun-cotton for storage purposes. After a patient and careful investigation, however, a Government Committee, specially appointed to inquire into the case, and to report on the special qualities of gun-cotton generally, has given such an opinion that the Government works in progress of erection at Waltham Abbey, for the manufacture of gun-cotton, which had been suspended for a time after the accident, have since been continued, and are now nearly completed. The explosion was undoubtedly caused by the presence of free acid, which must have found its way into the gun-cotton, after it had undergone the usual purification: free acid, in sufficient quantities to produce chemical action, was found to exist in some gun-cotton manufactured at Stowmarket, and delivered by Messrs. Prentice to the Government only a short time previously. If this accident has done nothing more, it has demonstrated the imperative necessity of extreme care in the manufacture of gun-cotton, and of effective supervision after it has been subsequently placed in store. As far as the substance itself is concerned there seems to be no reason to suppose that, if properly manufactured, there is any extraordinary danger attendant on its storage or manipulation when ordinary precautions are used. The result of an experiment in Prussia, with an analogous substance called dualine, may throw some light on the cause,

or perhaps it might be called gradual developement, of the Stow Market explosion. It was noticed that if a long train of dualine were laid on the ground and lit at one end, the combustion, at first slow, gradually increased in intensity, the flame became fiercer and fiercer, and the ignition more rapid, till at last it regularly exploded. Might not some process of this sort have taken place at Stowmarket? At first great accumulation of heat, developed throughout, by the decomposing action of the free acid, and favoured by the great heat of the weather, by which the explosive tendency of the whole mass was raised to a maximum, then the commencement, at some point, of the actual smouldering and ignition, which, by the species of reaction which occurred in the case of the train of dualine, developed itself into the disastrous series of explosions which occurred.

Suggested cause of Explosion.

The effect of compressed gun-cotton, fired with a detonating fuze, is marvellous. The power possessed by a detonation, of developing suddenly the full explosive force of gun-cotton, was discovered by Mr. Brown, of the Chemical Department, Woolwich, and several forms of detonating fuzes, to be fired either by electrical agency or by means of a Bickford's fuze, have been devised by Messrs. Abel and Brown. The electric detonator, as used in the service, is a modification of any of the several forms of Abel's electric fuze, a charge of fulminate of mercury being substituted for the powder priming, and the wooden fuze case being partly replaced by a conical tin case, which contains the charge of fulminate, and is of a size calculated to fit tightly into the perforations, with which the gun-cotton discs are provided.

Experiments with Gun-Cotton and Glyoxyline, Fired with a Detonating Fuse.

The following summary of the result of some experiments carried on with gun-cotton, and with glyoxyline, fired with and without detonation, under the auspices of the Royal Engineer Committee, at Chatham, on the 6th August, 1868, give an idea of the effect produced:—

Experiments were first made to show that neither of these substances, compressed gun-cotton or glyoxyline, will explode when unconfined and merely fired with an ordinary fuze, either time or electric, but that they require a detonating fuze to explode them under such conditions.

These experiments were most successful: the gun-cotton, when ignited with the ordinary fuze, only burning, and the glyoxyline being simply blown about without ignition. When the detonating fuze was used, the charges being still unconfined, both substances exploded with great violence, disintegrating the pieces of wood on which they were placed.

Five charges were fired successively against a stockade, formed of 1ft. 2in. square timbers, placed close together and firmly planted in the ground. The piles were chiefly of pine, except those specified to the contrary. The following is the result:

1st. Five pounds of glyoxyline, hung in a bag about two feet

from the ground. This blew in a hole, about one foot in diameter, resembling the effect that would have been produced if a round shot had passed through. Half the timber above the point of explosion was also carried away.

2nd. Ten pounds of glyoxyline, hung in a bag about two feet above the ground. This produced just double the effect of five pounds, the whole of the timber above the point of suspension being carried away.

3rd. Ten pounds of compressed gun-cotton laid along the foot of three piles. This cut a clean gap through two whole piles and half the third.

4th. Ten pounds of glyoxyline, laid in a train against three timbers, two of oak and one of pine. This cut through all three.

5th. Five pounds ten ounces of glyoxyline and five pounds of compressed gun-cotton. Each charge laid along the ground against three and a half piles, and consequently covering a space of seven piles altogether. The piles were cut half through, with the exception of one which was split completely through, though not severed. The line cut was three or four inches wide.

Experiment against Counter-scarp of St. Mary's front.

A plank being lowered over the counterscarp of St Mary's front, to a depth of 10 feet, the total height being 18 feet, the following charges were placed on it: 20 pounds of glyoxyline were laid along 3 feet of plank, and 20 pounds of gun-cotton along 3 feet more by its side.

The explosion was extremely sharp, and a partial breach of the following dimensions was formed: 7 feet high, 11 feet wide, and 20 inches in depth. The brickwork was very much shaken for some feet on either side of the breach, and pulverized for some inches more in depth.

Result of experiments.

The experiments indicate that these substances may prove exceedingly valuable for making breaches in timber and masonry, when portability and rapidity of action is required, as for example to breach a stockade or form a lodgment in the revetment of a work. Tamping may be dispensed with, which is a great advantage; but it must be borne in mind that, in order to produce a maximum of effect, absolute contact with the object to be destroyed is necessary, and for this purpose it would be convenient to prepare the charges beforehand, by placing them in bags or tin cases of suitable form, generally cylindrical and very long as compared to their diameter, so as to cover any space required.

Some further experiments were tried on the 5th September, 1868, against the same stockade. The breaches formerly made had been repaired, but certain alterations were introduced in its construction, viz., no earth was raised against the outside, the ground being level there; this earth was transferred to the inside and, together with blocks of granite, old iron guns and railway iron, was used to strut up the timbers and strengthen the stockade in the interior.

1st. Five pounds of compressed gun-cotton in discs were laid on the ground outside, against one of the logs, (of fir,) forming the stockade. This log was 13 inches square, and was strengthened behind by a block of granite weighing 9cwt., and earth. It was also secured to the adjoining logs by a riband with 7-inch nails. This charge, fired with a detonating fuze, cut through three-fourths of the log at the foot and forced the block of granite behind 1ft. 6in. to the rear.

It was the opinion of those present that the riband alone prevented the log from falling.

2nd. 7½lbs. of gun-cotton were now tried under similar circumstances, as in the first experiment, against a log of fir, 14ins. square. This log was only strengthened behind with earth 3ft. 6ins. high by 4ft. at base. The log was cut through and fell forward, the cut end being buried in the earth behind.

3rd. 7½lbs. of gun-cotton were placed equally on both sides of the corner log (of fir 15ins. square) of the stockade. This log was powerfully supported on the other two sides by those adjacent to it, forming the stockade. It was cut clean through and the bottom driven out 3ft., the log leaning in this position against the others.

4th. 7½lbs. of glyoxyline were placed loose on the ground against one log of fir 13ins. square, supported behind by small blocks of granite and earth 3ft. high by 4ft. at base. The log was cut completely through but remained standing, the top leaning forward about 2ft. beyond those adjacent to it. The effects of this glyoxyline charge were not so local as those of gun-cotton. With gun-cotton the adjacent logs were not touched; with this charge of glyoxyline, however, the two adjoining logs were much splintered. This difference of effect, between gun-cotton and glyoxyline, was probably due to the different manner in which the two materials were piled against the logs. The cotton, being in discs, was packed close up against the logs. The glyoxyline being in granules, was piled loosely against the logs, and therefore the centre of gravity was not so close to the logs as in the case of the gun-cotton. It (the glyoxyline) also fell over a little against the adjoining logs.

5th. A tin cylinder, 3½ins. in diameter and 3ft. 6ins. long, was loaded with 10lbs of gun-cotton in discs, which, to lengthen the charge, were separated by ½in. milled board. The cylinder was laid against three fir wood logs, 14ins. square each, which were supported behind by two 18-pounder iron guns and two pieces of railway iron, besides being secured to one another by ribands of wood and iron dogs. This chargo was fired with a Bickford's fuze, at the end of which was a detonating arrangement. The explosion, which was very violent, overthrew the two left hand logs, which fell forward, and very nearly severed the right one at the base, which however remained standing, being

prevented from falling by the ribands and dogs securing it to the adjoining log.

This concluded the experiments against the stockade.

6th. The gun-cotton discs were now tried against some palisades near the stockade. Four discs, weighing 4ozs. each, were placed one under each of four adjacent palisades, their edges being $9\frac{1}{2}$ins. apart. One of the outer discs was then fired, in order to see whether the explosion would ignite those adjoining it. This did not occur, only one was exploded which cut the palisade, against which it was placed, clean off level with the ground, but hardly even disturbed the adjoining discs.

Experiments on beams of timber, with gun-cotton and detonating fuze.

In order to test the effects of these explosives on beams of timber, some experiments were made on a wooden staging in the ditch, to the west of St. Mary's hornwork. The timber was of fir but very old and full of shakes.

One of the beams, 10ins. square, composing the staging, was bored with a vertical hole, $1\frac{1}{2}$in. in diameter, into which 2ozs. of gun-cotton were put. This charge completely severed the beam and split it, in several places, to a distance of 3 or 4ft. from the charge.

One ounce of gun-cotton was now tried under similar circumstances. This shattered the beam considerably, and split it so that it could be seen through, but did not sever it.

Large splinters of wood were thrown by these explosions to distances of as much as 20 yards.

Experiment on block of granite, with gun-cotton and detonating fuze.

A single disc of gun-cotton, weighing 1lb. 2ozs., was now placed on the top of a block of granite 3′ 9″ × 2′ 9″ and 2ft. deep. The block of granite had had several jumper holes bored in it, which had, however, been tamped up again, but must have weakened it considerably. The result of this explosion was that the block of granite was split vertically all round at an average distance of 2ins. from the outer edges, besides having a hole $1\frac{1}{2}$in. deep scooped out in the top of it at the seat of the charge. It was also much shaken and could easily have been picked to pieces. The result of the fracture round the stone was that, in a few days, the part split scaled off and fell away from the block.

The whole of these experiments would seem to prove that compressed gun-cotton, fired by a detonating fuze, is quite as powerful in its action, if not more so, than the mixture of gun-cotton and nitro-glycerine, called glyoxyline.

The average price of gun-cotton and glyoxyline would be about equal, being, (according to Mr. Abel), 20d. per pound weight, or $2\frac{1}{2}$ times the price of blasting powder; but as the effects of one pound of gun-cotton, for such purposes, appear to be equal to those of 4lbs. of gunpowder, it would in reality be 38 per cent. cheaper to employ gun-cotton. The specific gravity of compressed gun-cotton is the same as that of gunpowder, that of glyoxyline one third less.

Gun-cotton is more liable to absorb moisture than glyoxyline, though it is not permanently injured thereby. The transportation of nitro-glycerine dissolved in wood spirits, for the manufacture of the latter, is troublesome and expensive, and, unless carried about in this way, nitro-glycerine is very dangerous to move, whereas gun-cotton is not so. For actual service, however, Mr. Abel proposed to manufacture glyoxyline beforehand, and to coat the masses, (grains, discs, &c.,) with an impervious varnish, which would effectually enclose the nitro-glycerine and protect the preparation from the atmosphere. As, however, experiment has proved that it is in no respect superior to ordinary compressed gun-cotton, no steps have been taken to perfect its manufacture.

Experiments on gun-cotton by R. E. Committee.

Since the date of the proceedings here described, a large number of experiments have been carried on, under the auspices of the Royal Engineer Committee, with a view to determine the qualifications of compressed gun-cotton for land mining service, and especially as an agent for military demolitions. These have been printed in the form of a report, and need not therefore be repeated here. They demonstrate very clearly its great applicability for hasty demolitions, and its general usefulness in all cases, especially where violent, local, disruptive action is required.

Effect of compressed gun-cotton fired, under water, with detonating fuze.

The effects of these explosives are so powerfully concentrated and local, that it can hardly be doubted but that, if sufficient quantities were used, iron plates of considerable thickness could be pierced by them, especially under water.

In order to test its value for such a purpose, a few small charges of compressed gun-cotton have been fired, with a detonating fuze, under water, with the following result:—

1st. A charge of 3lbs. $0\frac{1}{4}$oz. was fired at our experimental target, (the squares of which are of fir 14in. square and 1in. thick), at a distance of 20ft. from the target and with 7ft. 6in. immersion; this broke 22 squares.

2nd. 3lbs. $0\frac{3}{4}$oz., 30ft distant from the target, and with 7ft. 6in. immersion, broke 10 squares.

20lbs. of powder, at a distance of 20ft., produced less result than this charge of gun-cotton at 30ft.

With both these experiments the shock experienced was most violent. The sprats and small whiting, for a considerable distance above the point of the explosion, were killed and drifted past in great numbers.

The above two experiments were made to test the comparative strength of the explosion of gunpowder and its equivalent of gun-cotton.

Comparative effect of powder and gun-cotton fired with

3rd. Charges of 15lbs. of powder and $3\frac{3}{4}$ of gun-cotton were placed on the mud and fired at high water, at a depth of 10ft. The charges were fired together, and the columns of water were observed to be about equal, but more mud was intermixed in the column of water thrown up by the powder.

detonating fuze, under water, on a muddy bottom.

The craters were examined at low water, when they were high and dry.

Each crater was found to be 9ft. in diameter, the gun-cotton crater was 2ft. deep, and the gunpowder crater 4ft. deep.

It would appear from this, that the shock of the gun-cotton explosion only compressed the mud in a downward direction, and the mud so compressed afterwards recovered, to a certain extent, its original position.

In the gunpowder crater the mud was less violently but more thoroughly thrust aside, and thus a deeper hole was made.

The lateral effect, which was really what we wanted to arrive at, was about equal, the charges of powder and gun-cotton being as 4 to 1.

Against an air backing, which would be the condition presented by a ship's side, a decided superiority for the gun-cotton is shewn in the first and second experiments.

Before any definite conclusions can be arrived at, experiments on a larger scale must be undertaken. It may however be laid down as an established fact, that the local action produced by a charge of gun-cotton, ignited by a detonating fuze, is enormous, that this effect is quite independent of tamping, except in loose or soft material, such as earth, and that the instantaneous explosion produced is in no way affected by a want of absolute contact, or by a small interval, between the discs, grains or masses composing the charge, as shown by the 5th experiment of the 5th September, 1868; or in other words, that no compression is required at the moment of ignition. This, in submarine mining, is a very great point gained, as it does away with the necessity for considering the strength of case, as far as the developement of the explosive force is concerned; a thoroughly watertight envelope, of sufficient strength to resist the pressure of the water, at the depth to which it is required to be submerged, being alone required. The certainty of immense local action being, as already stated, established, it only remains to be proved that the radius of destructive effect is at any rate equal, with equal weights, to gunpowder, to relieve us from many difficulties to which submarine explosions are at present liable, and it is to be hoped that this very desirable result may be arrived at.

Proposed experiment to test effect of gun-cotton against an iron-clad ship of war.

In order to test the effect of a charge of gun-cotton, of the size which would be used on service, against an enemy's ships, an experiment is about to be tried against a target, made to represent the bottom of an iron clad. This target is now in process of being attached to H. M. Ship "Oberon." This experiment has been strongly recommended by every Committee which has investigated the question of submarine mines, and it is one that is absolutely necessary to determine both the value of our war vessels, as at present constructed, to resist a submarine explosion, and the means of attack which we might use against those of an enemy.

Relative values of gunpowder, gun-cotton, and nitro-glycerine examined theorecically and themically.

In a very carefully written article, which appeared in *Engineering* of the 12th February, 1869, the relative mechanical forces generated by the explosion of gunpowder, gun-cotton, and nitro-glycerine have been determined theoretically and chemically, the pressure of the atmosphere being taken at 15lbs. on the square inch, to be as follows:—1 grain of gunpowder, when fired, produces a pressure of 200lbs. on the square inch; 1 grain of gun-cotton produces a pressure of 1,204lbs. on the square inch;* and 1 grain of nitro-glycerine produces a pressure of 1,167lbs. on the square inch.

It is probable that these values are not far from the truth, provided the explosion takes place under exceptionally favourable circumstances as to strength of case and completeness and rapidity of ignition, but such conditions would very rarely occur in practice.

A maximum of effect probably obtained by firing gun-cotton with a detonating fuze.

Perhaps the nearest approach to such perfection of ignition is obtained in the case of gun-cotton or glyoxyline and also with gunpowder, fired with a detonating fuze; and, if this theory be true, we may assume that the explosive effect of a charge of either of these substances, when fired with this particular form of fuze, under favourable conditions, approaches very nearly to a maximum or, in other words, to the effect which would be produced by the same charge, fired with an ordinary fuze, and contained in a case, the strength of which had been calculated to a nicety, so as just to exert the proper pressure to develope the maximum force at the moment of ignition, and yet not so strong as, in the smallest degree, to reduce that force by the pressure required to burst too strong a case.

Gun-cotton non-explosive when wet.

One great advantage of compressed gun-cotton is that, if ignited in a free open space, it simply burns without explosion, and that in order to render it incombustible it is only necessary to wet it. This wetting does not injure it in the least degree, and when dried again it is as good as ever. A drowned charge may consequently be restored to a perfectly efficient state. This property, together with the greater security for storage and manipulation consequent thereon, gives it a great advantage over gunpowder. Gun-cotton, in its ordinary state, contains about two per cent. of moisture. In order to test the rate at which it might be dried in air at the ordinary temperature, some discs were thoroughly saturated with water and hung up in a shed: these returned to their state of dryness and were fit for use in 10 days, the weather at the time being dull and wintry. In order to dry it more quickly the sun or artificial heat may be employed without danger, if ordinary precautions are used.

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* This result is based on data, derived from the forms of gun-cotton originally manufactured as to density and consequent weight, viz., 11lbs. to the cubic foot. Compressed gun-cotton weighs considerably more: nearly as much as gunpowder.

Suggested mixture of nitre or chlorate of potash with gun-cotton.

Towards the close of the late civil war in the United States, a good deal of gun-cotton was imported by the Confederates, but it does not appear to have been used by them.

Mr. Abel, War Department Chemist, has recently been trying some experiments, by incorporating large proportions of nitrate of potash or chlorate of potash with the compressed gun-cotton. The results obtained with either of these substances, show that a decided increase of explosive power is obtained from a given weight of gun-cotton, and further experiments are about to be made, to determine the proportions in which they may be most advantageously added, as well as to test the general value of the mixture, as compared with ordinary compressed gun-cotton and other explosives. The addition seems to be practicable; a considerable reduction being thereby effected in the cost of a given weight of the explosive, without material alteration of the specific gravity of the original gun-cotton, and without rendering it in any degree more dangerous to handle or store.

Nitro-glycerine.

The third explosive alluded to is nitro-glycerine. Some experiments, with a view to testing its capabilities for submarine work, were made by the United States Government, but with what result is not stated. Our experience of it, derived from experiments made at Chatham, is however such as to lead us to discard it for the above purpose. Its advantages are the very compact form in which charges might be arranged, its greater explosive effect, weight for weight, as compared with gunpowder, six of powder,* under ordinary conditions, being, said to be, about equivalent to one of nitro-glycerine, the peculiarly damaging effect of its explosion, when the charge is in absolute contact, or nearly so, and that leakage of water does not prevent its ignition. It is however extremely dangerous to store, and its effects upon those working with it seem prejudicial to health. Further, it seems to require much care in arranging the charge for ignition, and we found that, unless confined in a very strong vessel, such as a strong iron case or shell for instance, there was no certainty that it would be fired by an Abel's fuze, specially prepared for the purpose; it seems to require a large amount of compression, or to be submitted to concussion, at the moment of ignition. This latter failing might possibly be got over, but its other disadvantages are quite sufficient to condemn it as an explosive agent for submarine mines.

Dynamite.

Another substance, which might be used for submarine mining purposes, is "Dynamite." This may be described as a mixture of nitro-glycerine and silica, by which the former is said to be made as safe to handle as ordinary gunpowder. Its discovery is due to Mr. Nobel, a Swedish engineer. The question of safety, in carrying, storing, and manipulating this substance, requires

* This seems to be too high an estimate, probably four to one would be nearer the mark.

further testing; but the results hitherto obtained indicate that the porous silicious earth, which, in the preparation of Dynamite, is saturated with nitro-glycerine under a definite pressure, retains the explosive liquid very effectively, so that the latter does not exude, unless submitted to a pressure more powerful than that under which it is prepared. One of the most serious defects of dynamite is the readiness with which it freezes (at about 50 deg. F.); in the frozen condition it cannot be exploded, except by means of very special arrangements, and requires, therefore, to be thawed by exposure to heat. Serious accidents have occurred in carrying out this operation. The following experiments with submarine mines filled with dynamite, made in September, 1868, at Carlskrona, Sweden, give some idea of its effects:—

Experiment with Dynamite against hull of a 60-gun frigate at Carlskrona.

The target was the hull of a 60-gun frigate, which had been built in 1844; her timbers and planking were quite sound; timbers of oak about 13ins. square, frames 6ins. apart; planking of Swedish pine $5\frac{1}{2}$ins. thick; bottom strengthened inside with wrought iron diagonal bands, 6ins. × $1\frac{1}{4}$ins.; inside planking, running half way up to the battery deck, of oak 6ins. thick. The hull had been "razé" down to the battery deck, and the copper removed. The chief object was to ascertain the effect of dynamite, in a contact mine, against a strong wooden vessel, as well as against a double bottomed iron vessel and, with this object in view, a quadrangular opening had been effected on the port side, and filled with a construction representing a strong double iron bottom, firmly fastened to an oaken frame, that had been put on inside, on the four sides of the opening, and with through going bolts 1 inch in diameter, to the timbers. The mines were arranged as follows:—

Starboard side, No. 1. About amidship, 7 feet below water line, with the centre of the mine 2ft. 2ins. from the bottom of the ship; charge 13lbs. of dynamite in a thin iron case ($\frac{1}{12}$in. plate). The mines, although representing contact mines, were placed some little distance from the ship, on the supposition that they would or might be pushed to some distance away from the ship, after striking, before they exploded.

No. 2. About 40ft. from stern; $7\frac{3}{4}$ft. below the water line, centre of mine 3ft. from the bottom of the ship; charge 16lbs. of dynamite, in a glass vessel.

Port side, No. 1. About 30ft. from the stern, $5\frac{3}{4}$ft. below the water line, 2ft. from the ship's bottom; charge 16lbs. of dynamite in an iron case, of $\frac{1}{12}$in. plate.

No. 2. About 40ft. from No. 1, $6\frac{1}{2}$ft. below the water line, 2ft. 2ins. from the ship's bottom; charge 10lbs. of dynamite in a case as above.

No. 3. 2ft. 2ins. from the centre of the iron bottom, 7ft. 4ins. below the water line; charge 13lbs. of dynamite in a case as above.

These five mines were fired at the same moment, the hull was lifted about a foot, and sunk in $1\frac{1}{2}$ minutes.

Effect of the mines.

The wreck having been docked, the effect of the different mines were found to be as follows.:—

Starboard, No. 1. Timbers broken and thrown inside, into the hold, on a space of about 15ft. by 8ft., leaving a hole of those dimensions; three more timbers on one side of the hole broken, inside oak planking rent off on a length of 14ft., two iron bands torn up and bent, one of them broken in two places; outside planking off on a space of about 21ft. by 12ft., several planks, still higher up, broken.

No. 2. Timbers blown away on a space about 8ft. square, inside planking off on a length of 20ft., two iron bands broken, and torn up and bent; outside planking off on a space of about 19ft. by 12ft.

Port side, No. 1. Timbers blown away on a space 10ft. 6ins. by 12ft. at one end and 6ft. at the other, inside planking off for a length of 14ft., one iron band torn up, one broken; outside planking off, on a space 18ft. × 25ft. and 15ft.

No. 2. Timbers blown away on a space 4ft. in length and 16ft. in height; on the sides of this hole 10 timbers were broken, two iron bands torn up, one broken; inside planking off for a length of about 20ft., outside planking off for a space of about 20ft. and 23ft. × 10ft. and 13ft.

No. 3. The gas sphere had hit the middle of the outside plates on one of the angle iron ribs. This rib was torn from the timbers and bent up, nearly 2ft. in the middle, but not broken. There was an oval hole in the outside plates 4ft. × 3ft. between two ribs, which ribs, with the plates on edge rivetted to them, were bulged out about 5ins. The inner plate, one large piece, was blown up in a vertical position, after having cut all the bolts and rivets, 60 of 1in. and 30 of $\frac{3}{4}$in., save those that fastened the lower side to the oaken frame and timbers. On a length of about 30ft. and height of about 20ft. the bottom, on all sides of the iron construction, had been bent inwards: the greatest bend was about 5in.; three deck beams above had been broken.

By the joint effect of all the mines, almost all the iron deck beam-knees had been rent from the side, and there was an opening between deck and hull on both sides for a length of about 130ft.

Lithofracteur.

Lithofracteur is another combination, in which nitro-glycerine forms the explosive element. It is the invention of Mr. Engels, of Cologne, who has recently brought it to public notice. The manufacturers speak little of its composition, but analyses of it have been published in Germany, and it is well known to be simply a modification of dynamite, containing less nitro-glycerine than that preparation, and the siliceous earth being partly replaced by saltpetre, a little sulphur, and coarsely powdered coal. It is of a dark brown, sometimes almost black colour, and is soft

and plastic, being somewhat moist with nitro-glycerine. It is made up in small rolls, like dynamite, enclosed in water-proof paper.

Numerous experiments have been made with it, which go to prove that it is safe to handle, and that it will only explode when ignited by a detonation. It freezes at a comparatively high temperature, and when in a frozen state, is difficult of ignition, even when detonation is employed. Its explosive effects are similar to those of other compounds of nitro-glycerine, its action, as far as may be judged from the experiments yet made, being violent and local. No experiments appear as yet to have been made to obtain an idea of its working effects as compared with gunpowder and other explosives, but it is probable that, in this respect, it is similar to the kindred compound called dynamite. We have, as yet, no experience of its qualifications for storage for lengthened periods, it being an invention of comparatively recent date.

Operations against the wreck of th schooner "Alarm."

The following account extracted from the the *Standard* newspaper of the 26th of March, 1872, gives an idea of the value of this explosive for submarine purposes. The operations were undertaken against the wreck of the schooner "Alarm," sunk in the river Parratt, just above its entrance into the Bristol Channel, and offering a serious impediment to the navigation at this point, which rendered her removal necessary; they were carried on under the superintendence of Mr. France.

" The charges employed were two, fired distinctly, and for this reason—that the hull was so filled with sand that its influence in checking the effect of a single charge might have been sufficiently great to mar results. The first charge of 50lb. of lithofracteur was placed in the after part of the hull, pushed a short distance under the deck, on the top of the sand, close to the mizenmast. It was fired with a Bennett's fuze of 50 feet in length (in duplicate to ensure effect), the fuze burning for 17 minutes, when the explosion took place. The mast was blown into the air 60 feet, like a rocket stick, and the afterpart of the vessel entirely cleared away. The cone of water thrown up probably exceeded 200 feet. The second charge of 50lb. was placed outside the remainder of the vessel, beneath the side to which the hull heeled, and fired similarly with Bickford fuze. This completely finished her, a large hole being made at this spot 10 feet in depth in the river bed. The small debris remaining in the bottom of the river were subsequently cleared with charges of a few pounds each; and thus was the navigation entirely cleared by these simple but most effective operations, and that, too, with a small amount of this explosive, which, it is not too much to say, several tons of gunpowder would have failed to realize, on account of the difficulty of employing it and the

difference in its action.* It is also worthy of note that the first charge of lithofracteur was enclosed in a tarred water-proof box; but that the second was placed in the form of loose cartridges in a mere deal packing case, into which the water had free ingress; nevertheless, the explosion was even more efficient than the first, showing how admirable for submarine work this lithofracteur is. Very great credit is due to the diver, William Sully, of Cardiff, for the admirable manner in which he performed his work and the pluck with which he ventured down in a stream running at the rate of seven knots an hour."

The latter part of this account would appear to warrant the conclusion that lithofracteur is unaffected by contact with water, but the results of other experiments have shown that the nitro-glycerine begins to separate and run out of the charges, the moment the preparation comes into actual contact with water. In the operation above referred to, the deal packing case and water-proof envelopes must have excluded the water from the explosive sufficiently long to admit of its being successfully fired.

Glyoxyline.

Another explosive agent is Glyoxyline, invented by Mr. Abel, Chemist to the War Department. This is a compound of gun-cotton and nitro-glycerine, prepared by soaking the former, in a granulated state, or in the form of discs or pellets, in the latter of which it will take up nearly its own weight; the masses are then coated with a varnish, which perfectly excludes air and encloses the nitro-glycerine; when thus manufactured, it is said to be as safe to handle as ordinary gunpowder. Its explosive effect, when fired with a detonating fuze, is very similar to that of gun-cotton fired with the same fuze, and as the latter is very much safer to handle, it is consequently greatly to be preferred, unless future experiments should develop any peculiar advantages to be derived from the use of glyoxyline.

Picric powder.

Picric powder, which is formed by incorporating ammonium picrate and saltpetre in equal proportions, has been suggested as an explosive for submarine mines. It may possibly be found useful under certain circumstances, in the event of adequate supplies of gun-cotton not being available; though much more powerful than gunpowder, it is known to be less so than gun-cotton, but, until we know a little more about its qualifications, it is impossible to give any definite opinion as to its value. The Torpedo Committee, to whom it has been referred, have recommended that a few experiments should be made to enable them to report upon it for submarine mining purposes.

Schultz powder.

Schultz powder, which partakes more of the character of gun-cotton than gunpowder, has been suggested for submarine mining purposes. It is sometimes called wood gunpowder, and is prepared by treating wood fibre with nitric and sulphuric acids

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* This is an assertion which requires qualification.

in a similar manner to that in which gun-cotton is manufactured, but only to such an extent as to render it slightly explosive. The product is then impregnated with a mixture of saltpetre and chlorate of potash. The result is a light granular material, exploding more violently than gunpowder, when strongly confined. It is inferior in uniformity to gun-cotton and nitro-glycerine preparations.

Dualine. Dualine is said to be a mixture of Schultz powder and nitro-glycerine, somewhat similar, it is supposed, to glyoxyline, which has already been described. This explosive was extensively used by the Germans, during the late war of 1870-71, for their submarine mines. Taken with reference to its simple explosive qualities they seem to report favourably upon it, on the other hand, they consider it extremely dangerous to handle and store. The charges of this substance, in some of the submarine mines taken up at the end of the war, and which had consequently been under water for several months, are said to have been in very good condition. Very strict precautions are adopted concerning it, for example, that required for the defence of Wilhelmshafen, the new German Imperial Dockyard in the North Sea, is kept on board a small vessel in an unfrequented corner of the Bay of Jahde and no one is allowed to go near it except when it is required for use.

Other explosives of a dangerous nature. It is of importance to keep in view the necessity of using an explosive substance for submarine, or indeed for any mining purposes, which, though powerful in its effects when required to act, and of a nature suitable to the work to be done, may yet be safely stored and manipulated when ordinary care is used; and we may, on this account, at once put aside the many compounds which, though at first sight presenting advantages, are liable to explode unless handled with extreme care.

Preparations, consisting of potassium picrate and salt petre or chlorate of potash, are examples of this class, and the fearful explosion of such a mixture, which recently occurred in Paris, is enough to condemn it.

Compressed gun-cotton the most suitable explosive for submarine mines. After a very careful investigation into the subject, and having taken into consideration the various qualifications of the several explosives suggested, the Torpedo Committee have approved of compressed gun-cotton, fired with a detonating fuze, as most suitable for submarine mining purposes; and the Government have decided on erecting an establishment for its manufacture at Waltham Abbey, which is now nearly ready to commence work. Where gun-cotton is not procurable, gunpowder, fired, if possible, with a detonating fuze may be used.

Size of charge. The next point to be considered is the amount of the charge, of powder or other explosive, to be employed in each mine. On this subject we have still a good deal to learn and, before we can bring the calculation of charges for submarine mines, to the same

degree of certainty which has been attained as regards those for ordinary earth, rock, or masonry, much remains to be done.

The points to be determined are the depth at which a given charge is most effective, the lateral and vertical range at which a certain charge may be relied on, to produce a given result, and what that result would be on the bottom of a vessel as strongly built as a modern ship of war. The first of these questions has only been partially worked out, the last, (the effect on the bottom of an ironclad) has never been tried at all, though frequently recommended by successive Committees.

Experience of Confederates on size of charge.

The recommendations of the Confederates on this point are described by Captain Harding Steward, R.E., in his *Notes on Submarine Mines*, as follows:—"With submerged torpedoes, as employed by the Confederates, the regulation of the charge depended on the depth of water, the nature of the bottom* and structure of the ships to be expected, except in the case of small torpedoes, moored a little below the surface and arranged for contact. With these the proximity of the charge to the object altered the conditions. The following scale of charges, suitable to depths from two fathoms and upwards, was made for use in the James River, where the bottom is very soft. It is based on data, obtained from the destruction of wooden vessels of 800 tons, by the Confederates, also from experiments, and is suitable to strongly built wooden vessels up to 1,000 tons:—

Charges for a soft bottom for 1000 ton vessel.

2 fathoms	...	...	300lbs. of powder.
3 "	...	...	600 " "
4 "	...	...	900 " "
5 "	...	...	1,200 " "
6 "	...	...	1,500 " "
7 "	...	...	1,800 " "
8 "	...	...	2,400 " "

Smaller charges for a hard bottom.

With hard bottoms the charges could be diminished, for the waste of powder is not so great. In the case of a rocky bottom, as much as 25 per cent. may be deducted, according to the American experiments, because the rebound of the portion of the gas that acts downwards is almost coincident with the upstroke of the rest. These charges, even considering the objects in view, appear excessive, but it must be remembered that the Confederates used only one fuze for ignition. With a proper arrangement for igniting the charges at several points a reduction might have been made amounting to 40 per cent. As I have before mentioned, the employment of large charges was made with a view of controlling a large area and destroying a vessel through the commotion of the water, when beyond the direct action of the charge. This plan may be a good one with small vessels, but the worst feature of the system is the fact that, as in some cases, the result depends

* The bottom of the channel, not of the ships.

fting powers of the charge, the quantity of powder sarily be increased in proportion to the size of the)ected. A progressive increase of one-third of the ven in the foregoing scale, for every extra thousand .asurement, was considered by the officer superintending ; operations in the South, as the least that could be e case of large vessels. This is no doubt true, but with 3,000 to 4,000 tons it brings the charges to quantities for proper arrangement."

Charges i creased f larger ves. sels.

ırds this scale of charges, recommended by the Con- it seems to be somewhat fallacious to go on increasing ;es without limit, according to the depth, and we may safely assume some point beyond which the charges .ot be increased. Probably 2,000lbs. of gunpowder or of gun-cotton might, for the present, be assumed as a n, which ought to be sufficient to break the bottom of sel, however strongly she may be built, if fired in a osition with reference to her. As the tonnage of a vessel s so generally does her strength, but so also does her of water and, consequent upon this latter fact, if the were always kept as deep as possible, a larger vessel ılways find a larger charge, in proportion to her size, in roximity to her, wherever there was sufficient water to ıer to pass. On the contrary, the large charge would y reach a smaller vessel, and as effectually damage her, :standing the cushion of water intervening.

'ıe Sixteenth Volume of the Professional Papers of the of Royal Engineers, a description is given by Lieutenant J. Wallace, R.E., of the means adopted for blowing up .vrecks of vessels in the River Hoogly. Lieut. Wallace's -ions as to the size of the charges to be most advantageously ·ed, as derived from these experiments, are as follows :—

ıe size of the charges, when they cannot be placed inside or the wreck should, in my opinion, be regulated by the depth · water. In from four to nine fathoms, 450 and 500lbs. ;es were found to answer very well, but I think they might been increased with advantage at the latter depth."

Size of charges us in destruc- tion of wrecks in t Hoogly.

Between three and four fathoms, 250 and 300lbs. charges generally the most economical : a larger quantity simply ›ws the water to a greater height without producing a corres- ıding increase in destructive effect."

It is to be remarked, however, that the conditions were some- .vhat different from those under which a submarine mine would be called on to act. In the case of the wrecks there was an equal pressure of water inside and outside, whereas, with a submarine mine, there would be air inside the ship; the charges were, more- over, in every case, arranged to be in actual contact with the vessel, and were intended simply to break up the wreck in such

a way as to clear the channel, whereas, a submarine mine, to be really effective, ought to act destructively on a vessel at some little distance. That this may be done there is no doubt, and our experience tells us that, especially at the greater depths, charges of this size would be found much too small for use, except as contact mines.

Charges in Confederate drifting torpedoes too small.

The charges used by the Confederates, in their drifting torpedoes, were usually about 100lbs. of powder, and were productive of comparatively small results ; this is in a great measure accounted for by the fact of their explosion occurring at, or very near, the surface of the water. The charges they employed in the attack of vessels with their torpedo boats, were 50lbs. of powder, which proved ineffective in many cases, and may be pronounced too small for the purpose required.

Experiments made at Chatham for Floating Obstruction Committee.

A great number of experiments have been made at Chatham, for the Floating Obstruction Committee, with a view to determine the depth at which a given charge is most effective, as well as the radius of explosive effect, or distance from such charge at which a vessel would be destroyed. This series was not completed before the Committee was dissolved. The results obtained give us the following information:—

First, that 100lbs. of powder is most effective at a depth of 10ft., that is to say, that, as it approaches nearer to the surface, much of its energy is lost, by the escape of the gas towards the air, and the lateral effect is reduced proportionately. Actually on the surface the lateral force of explosion would be at a minimum, which would, in a great measure, account for the small amount of damage caused by the Confederate 100lbs. charges, in the mechanical contrivances already alluded to. Again, if the charge be lowered the explosive effect would be absorbed by the intervening cushion of water, unless the vessel's draft of water was sufficient to bring her in contact, or nearly so, with the mine.

Till an experiment has been tried against a target to represent the bottom of an ironclad ship, it is impossible to say at what distances and depths the larger charges may be most effectively employed. It is to be hoped that, when the preparations now in progress for this experiment are completed, this problem will be solved.

Radius of explosive effect.

Secondly, from the observation of the results of certain experiments, made with charges of known sizes, fired on the bottom with different superincumbent depths of water, by the Floating Obstruction Committee, it has been found that, when a charge is immersed to that depth at which it is most effective, the radius of explosive effect may be derived from the equation,

$$R = \sqrt[3]{8. c},$$

where R is the radius of explosive effect in feet, and c the charge of gunpowder, in lbs. Where gun-cotton, fired with a detonating

fuze, is used, assuming the effect to be four times that of gunpowder, the value of c would have to be multiplied by 4 and the equation would stand thus—

$$R = \sqrt[3]{32.\ c},$$

and so on for any other explosive substance used, the proportionate effect, as compared with gunpowder, having been obtained. The relations expressed in this equation are completely borne out by the result of an Austrian experiment, on a large scale, in which precisely the same effect was obtained, in proportion to the size of the charge employed.

When the results of the larger charges have been obtained, it is possible that these deductions may be somewhat modified but, in the meantime, they seem to be sufficiently near the mark to be adopted for any calculations we may have to make.

Experiment on H. M. S. "Terpsichore."

In an experiment tried at Chatham, on H.M.S. "Terpsichore," a charge of 150lbs. of fine grain rifle powder, placed in 22 ft. of water, on the bottom of the river Medway, at a distance of 12 ft. below the keel of the vessel, and 2 ft. horizontally clear of the side, made a hole, at a distance of 19 ft., in a direct line, and nearly in a vertical direction, of such size as to sink the ship in a few minutes. We learn from the result of the experiment that the explosive force of a charge acts most strongly, whatever the depth may be at which it is submerged, in the direction of the line of least resistance, which in this case was through the bottom of the vessel, precisely at the point where the charge broke through.

Experiments on H. M. S. "America."

In the Spring of 1866, a number of experiments were tried at Portsmouth, by firing several charges of various sizes, suspended at different horizontal distances from the sides of H.M.S. "America," and at different depths of water. No very decisive results were obtained from these experiments, but the fact that the destructive effect of charges, in a horizontal direction, diminishes rapidly as the distance increases is to be remarked.

Von Scheliha's experiments.

In his Treatise on Coast Defence, recently published, Colonel Von Scheliha gives the result of several experiments which he made himself. Some of these results are very anomalous and do not at all bear out preconceived notions. They, however, confirm the idea, of which there can now be no doubt, that the explosive effect of a charge acts most strongly in the direction of the surface, or line of least resistance, whatever may be the depth of the water.

General conclusions as to the effect of a charge fired under water.

The destructive effect would not appear to be limited to the area from which the gas of the exploded charge drives away the water. The first effect of the explosion would be the formation of a globe of gas, exerting a pressure equal in all directions. Water being practically incompressible, the effect in the direction of the sides is a force, which is constantly communicated horizon-

tally through the water as a shock, for a considerable distance; but in consequence of the ready transmission of this shock, in all directions horizontally, there is but little damaging effect. The effect of the gas in a vertical direction is, no doubt, much enhanced by its very low specific gravity as compared with water, but its expansion, originally due to the great heat which caused its production, is immediately checked by the cooling influence of the surrounding water. The gas then, in the first instance, would appear to lift bodily a column of water immediately overlying the primary globe of explosion; as soon as this column of water is set in motion the gas commences to force itself through it, and we have a column of spray, or a mechanical mixture of gas and water, ejected above the surface of the water. In the event of a ship being immediately over the charge, if the strength of her timbers were greater than the resistance of the depth of water on each side, the line of least resistance would evidently be to the right and left of the vessel, and the greatest effect of that charge would be just clear of the ship's sides. But as in the majority of cases, when a charge is exploded near the bottom of a ship, the resistance of the timbers against an upward blow would be less than that of a column of 18 or 20 feet of water, it would take effect in that line of least resistance or through the ship; in such a case there would probably be little indication of an explosion on each side of the ship, except a slight disturbance on the surface of the water. In this case the water in all directions, except between the charge and the ship, acts as a most efficient tamping or an incompressible medium. That this water tamping is most effectual would be best exemplified, by first exploding a charge placed on the surface of the water against a ship's side, noting the effect and then exploding a similar charge against the ship's side, but immersed 10 or 15 feet. In the first case, however, the explosive effect of the powder would be in one respect greater, owing to the absence of cooling of the gas, the explosion being principally in air. The difference of strength in the side of a ship, at the water line and 10 feet below the water line, must in such an experiment be taken into consideration, as it is presumed that in a modern ship of war a greater strength will always be provided at the water line than under the quarter.

There is an additional amount of water ejected in the explosion of a submarine mine, due to the pressure of the atmosphere forcing the surrounding water to fill up the vacuum caused by the explosion, and a considerable portion of the water is consequently drawn up in the wake of the original column overlying the charge.

Approximate rule for determination of sizes of charges.

As already stated, we are still far from being able to give any fixed rule, by which the sizes of charges may be calculated, but as it is better to be above than below the mark, the following, derived from the result of experiments carried on by the Torpedo Com-

mittee, may be assumed as sufficiently near for all practical purposes. The charges recommended, and for which cases have been designed and are now in store, are 100lbs., 250lbs., 500lbs., and 1000lbs.* of gun-cotton.

The 100lbs. charges are suitable for situations in which they could be fired when actually in contact with an enemy's ship. They should be placed at a depth of from 10 to 20 feet of water.

The 250lbs. mines would be provided with detached circuit closers, to enable them to be submerged at a suitable depth of water to suit the larger charges contained in them. They would probably be most effective at a depth of from 20 to 35 feet of water.

The 500lbs. mines would also be provided with detached circuit closers. They would probably be most effective at a depth of from 35 to 50 feet of water.

The 1000lbs. mines would similarly be provided with detached circuit closers. They would probably be most effective at a depth of from 50 to 70 feet of water.

These are all for gun-cotton. There are however many places where gunpowder only may be obtainable, and if it be employed, it may be assumed that its explosive effect would be about one-fourth that of gun-cotton and the depths should be reduced accordingly.

In considering the series of charges, given by Captain Harding Steward, as the result of the Confederate experiments, we find that the square of the depth in feet gives very nearly the sizes of the charges of powder in pounds, for depths between 20 and 40 feet, for mines laid on a hard bottom, and if we add one-fourth to the sizes of charges thus obtained, for soft muddy bottoms or buoyant mines held by moorings, we shall have a rough means of approximately calculating the charges of gunpowder required between depths of 20 and 40 feet. This relation of charges, as the squares of the depth, though not derived from any mathematical relationship between the forces existing, is a rule easily remembered, and which seems to give a result sufficiently near the mark for practical purposes. Charges of the sizes above mentioned would probably be sufficient to sink any vessel passing fairly over them. The ships would draw more water in proportion to their size and strength and, bearing in mind the rule that where practicable the mines should always be laid on the bottom, they would find increased charges opposed to them in proportion to their draft of water.

The force required to break through the bottom of a vessel, so strongly built as a modern man of war, has yet to be determined, and may lead to considerable modifications in the sizes of charges here suggested.

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* No 1000lbs. cases have yet been placed in the War Department stores.

Interval between mines in a line.

The next point to be considered is the interval to be allowed between two adjacent charges, in the same line of submarine mines, so that the explosion of one shall not injure those next to it, or disturb the arrangement of their electric cables, and yet that the chance of a vessel running between any two, and thus escaping injury, may be reduced to a minimum.

This is a point on which nothing has yet been definitely determined, but experiments have been made with charges of 432lbs. of gun-cotton with the following results:—

The interval between any two mines, which would place one at such a distance from the other as to secure safety, in the event of either being exploded, manifestly depends upon the size of the charges employed, or, in other words, the distance at which any given charge is calculated to act destructively. This may be approximately calculated, when gunpowder is used, from the equation $R = \sqrt[3]{8c}$ (see page 40), where R is the radius of destructive effect in feet. If then we place our mines in line at central intervals of twelve times R, our present experience, derived from the very few experiments tried, goes to show that they will be safe from the explosion of those adjacent to them. To find the safe interval for gun-cotton, or any other explosive used in a system of mines, it will only be necessary to multiply by the co-efficient, derived from actual comparison of the effect with that of gunpowder, to determine the value of R due thereto, and to arrange the mines in line at intervals of 12 R as before. This necessary interval between the charges in line, is one reason which renders the employment of two or more lines of mines essential to a proper maintenance of the defence. It also sufficiently explains the objects to be attained, in placing them in such a way that the charges in the second line shall cover the intervals in the first, and that those in the third shall cover the intervals in the second, and so on.

Experiments to determine the distance at which one mine is safe from the explosion of another.

The experiments from which this value, 12 R, is derived, were tried in the Medway in the Autumn and Winter of 1870.

1st experiment, tried off Gillingham, in the river Medway, on the 14th of September, 1870:—A charge of 432lbs. of gun-cotton was moored under a head of 37 feet of water and close to the bottom, and a series of cases, loaded with coal dust and with circuit closers or breakers attached, were similarly moored, at the same depth (37 feet of water), at horizontal distances from the first varying from 50 to 80 feet. The charge was fired with an electric detonating fuze. The case at the greatest distance, (80 feet), was completely destroyed and the dome of the circuit breaker attached to it was dented in and nearly collapsed. This clearly proves that a distance of 80 feet from a charge of 432lbs. of gun-cotton, fired with a detonating fuze, is much too little for the safety of its neighbours.

2nd experiment, tried off Gillingham, in the river Medway, on

the 11th October, 1870:—A charge of 432lbs. of gun-cotton, moored under a head of 27 feet of water, was surrounded by a series of cases, moored under a similar head of water, at horizontal distances varying from 70 to 120 feet. The charge was fired with a detonating fuze. The case at the 120 feet distance was dented in, but remained quite watertight:—the copper guard of the fuze piece had collapsed in consequence of pressure on the top and the earth connection with the fuzes had been ruptured. The circuit closer, which was of Mathieson's pattern, had its dome dented and its ebonite frame crushed; it showed indications of slight leakage, but still signalled when hit. The insulation of the electric cable remained uninjured. This again showed that, with the charge used, an interval of 120 feet would be much too little.

3rd experiment, tried in Long Reach, in the river Medway, on the 2nd of December, 1870:—A charge of 432lbs. of gun-cotton, moored under a head of 47 feet of water and close to the bottom, was surrounded by a series of cases, loaded with coal dust, moored under a similar head of water, at horizontal distances varying from 70 to 200 feet. The charge was fired with a detonating fuze. The case at the distance of 200 feet was dented in but did not leak; it was not provided with a circuit closer. This again showed clearly that 200 feet is still too small an interval for safety.

4th experiment, tried in Long Reach, in the river Medway, on the 23rd of December, 1870:—A charge of 432lbs. of gun-cotton, moored under a head of 27 feet of water, and with 27 feet of water between it and the bottom, was surrounded by a series of cases of the same size, loaded with coal dust, moored under a head of 27 feet of water, and with 27 feet of water between them and the bottom, at horizontal distances varying from 100 to 200 feet. The charge was fired with a detonating fuze. The case at 200 feet distance and the circuit closer, of Abel's pattern, attached to it were uninjured. The charge at 180 feet distance was also uninjured, but no opinion could be given concerning the circuit closer, of Mathieson's pattern, as it had been previously injured by a barge which had anchored in the vicinity. A charge at a distance of 115 feet was slightly dented at the ends but did not leak. The head of 27 feet of water, in this case, seems to be too small for the size of the charge used, namely, 432lbs. of gun-cotton. The depth, calculated by the square root, of the comparative charge of powder, gives a head of 42 feet of water, as that at which a charge of this size should be moored.

The iron cases, against which these three experiments were tried, were made of $\frac{3}{16}$ inch wrought iron of the best quality procurable, which is the thickness adopted for those approved for buoyant mines for service; the results may, therefore, be taken as affording approximate data for determining the distances of safety

required. It is manifest, however, that the question has not been definitely settled by these experiments, and that the series must be extended before the distances can be absolutely decided.

The following example illustrates the manner in which this distance may be calculated:—

Example of calculation.

Suppose the charge to be 432lbs. of gun-cotton, the radius of destructive effect, calculated from the equation

$$R=2\sqrt[3]{c},$$

c being the charge of gunpowder in pounds, or in this case $4 \times 432 = 1728$lbs., in this case, therefore,

$$R=2\sqrt[3]{1728}$$
$$=24 \text{ feet}$$

and the distance at which the mines would be safe from the explosion of those adjacent would be $12\ R = 12 \times 24 = 288$ feet.

Interval between each line of mines.

Again, with regard to the distance to be allowed between any two lines of mines, it is easily seen, by reference to *Plate* I., page 19, that just in proportion as we move our second and third lines back, we increase the chance for a vessel to pass safely through: it is, therefore, desirable to keep these lines as close together as the other conditions of the case will admit. These other conditions are—1st, the necessity for allowing a sufficient distance between the lines of mines, to enable the electric cables to be laid in a safe position midway between them. 2nd, the necessity for placing the lines at such intervals, that there shall be no confusion in determining the position of each mine, by intersection, after they have been submerged. This is absolutely necessary in case it is required to fire the mines by judgment, the position of a vessel being determined by intersection, or cross bearings as it is sometimes called. It is also necessary to facilitate the discovery of a mine, in case it is required at any time to take it up for inspection. And 3rd, the average length of a large ship of war, is an item which must be taken into consideration in determining the distance above required. Keeping these conditions in view, the intervals between the lines may be approximately determined and, as a general rule, they should never be at less than 150 yards or more than 300 yards apart, unless such an arrangement is incompatible with the peculiar circumstances of any particular position to be defended.

Further experiments required to determine distance of safety.

More experiments are necessary with a view to the determination of this question of distance, at which one charge would be safe from the effect of the explosion of another; till this is done the above general rules may be adopted.

Experience of Lieut. Wallace, R.E., as to distance of safety.

In the record of the destruction of wrecks in the river Hoogly, by Lieutenant Wallace, R.E., he mentions that one of two charges of 450lbs. each, placed 55 feet apart and at a depth of 48 feet of water, was destroyed by the explosion of the other, probably stove in, it is not said how damaged. This distance of 55 feet is

manifestly far too little for safety with a charge of that size; it is, however, mentioned here as one of the few experiments which in any way touch on this point.

Lieutenant Abney's formulæ for calculating height of column of water and radius of destructive effect of a given charge.

Lieutenant Abney, R.E., has suggested the following formulæ, theoretically arrived at: the first showing the relation between the height of a column of water, thrown up by a given charge, immersed to a given depth, and the second that between the radius of destructive effect, with reference to a given charge, immersed at its depth of maximum effect, and the thickness of an iron plate against which that charge is fired. Let c = the charge of gun-cotton in lbs.; d = the depth at which that charge is immersed, below the surface of the water, the charge being on the ground; H = the height of the column of water, thrown up above the surface by the explosion of the charge.

$$\text{Then } H = \frac{292 \sqrt[3]{c}}{d} \text{ very nearly.}$$

Again if a = the thickness, in inches, of an unfixed iron plate, against which the charge is to be fired; r = the radius of destructive effect in feet, when the charge is placed to gain the maximum effect vertically and horizontally; and if D be this depth, then

$$r = \frac{14{\cdot}5 \times d}{D} \times \sqrt[3]{\frac{c}{500}} \left(a^{\frac{4}{5}} + 2.5 \log c \right) \text{nearly.}$$

The factor 14·5 was calculated from the results of a charge of 432lbs. fired at $\frac{3}{16}$ inches of iron, given at page 44.

These formulæ gave, by calculation, very nearly the actual results obtained, in the experiments tried to discover the distance of safety of one charge from the explosion of its neighbour, referred to in page 45.

For gun-cotton charges, between 100lbs. and 2000lbs., Lieutenant Abney calculates the depth, from the surface, at which a maximum effect is obtained, as

$$= 6{\cdot}7 . c^{\frac{2}{9}}, \text{ nearly.}$$

CHAPTER IV.

Form and Construction of Case.

The next point to be considered is the form and construction of the case to contain the charge of powder, or other explosive.

Conditions to be fulfilled. Let us first enumerate the several conditions which it is necessary that this case should fulfil.

1st. It must be very water-tight, to prevent damage to the charge by leakage.

2nd. It must be sufficiently strong to bear handling, without danger of becoming leaky by straining, and must be able to sustain the external pressure due to the depth of water at which it is to be placed.

3rd. When gunpowder, or gun-cotton fired with an ordinary fuze, is used, it must be sufficiently strong to hold the charge together, as it were, for an instant at the moment of ignition, so that its full effect may be obtained, by as thorough a combustion as possible of that charge. When gun-cotton, fired with a detonating fuze, is used, our present experience indicates that the case need only fulfil the conditions, as regards strength, enumerated in paragraphs 1 and 2.

4th. In the case of a buoyant mine it must be capable of being arranged with a large excess of floatation, so that when moored it may remain as stationary as possible at the required point.

5th. It should be of such form as to be capable of being handled and moored conveniently.

6th. It should be of such form as to secure a thorough ignition of the charge with the smallest possible number of fuzes.

7th. It should be of such form as to be easy of construction, and not too costly.

General form of case. First, with reference to the form of case. Those hitherto used seem to have been either conical or cylindrical. The former appear to have been used by the Confederates as the general *Conical form of Confederates, for* shape for their self-acting mechanical torpedoes. The apex of the cone forms a convenient point to which the mooring cable may be attached, while the base, terminated by a curved portion, serves as an air chamber, giving the necessary buoyancy to keep

the mooring cable straight, and hold the mine in a comparatively stationary position in a current or tideway. The circumference of the base affords a good salient position on which to place the arms or nipples to be struck by a passing vessel. The conical form has however not been approved for our submarine system of mines.

small mechanical self-acting mines.

Cylindrical form for larger charges.

The cylindrical form appears to have been used by the Confederates, where they allowed their mines to rest on the bottom. The cylindrical shape admits of the explosive being stowed in a very convenient form and, for large charges, possesses advantages as far as the ignition is concerned, as will be hereafter described.

The Austrians have adopted a cylindrical shape for their buoyant charges, and those exhibited by them at Paris were of the forms shown in *Plate* III. These mines were arranged to be fired by electricity and, all things considered, the form seems well adapted for the sizes of charges recommended by them, viz., 3 cwt. of powder or 4 cwt. of gun-cotton, whether arranged to be laid on the ground or to be floated from moorings at any required depth.

Cylindrical form adopted for British Service.

Experiments show that the cylindrical is the best practical form of case for all sizes of mines; it combines simplicity of manufacture with compact shape, and has accordingly been adopted as our pattern for service. A spherical form would be theoretically the best, supposing a single point of ignition only to be used, because every part of the outside would be equi-distant from that centre of ignition; but the construction of a case of this shape would be comparatively costly, and a cylinder, the height of which approaches nearly to its diameter, is sufficiently near in form to a sphere for practical purposes.

Next as regards the material of which the cases may be most advantageously constructed.

Materials of which cases may be composed.

Several substances have been suggested and tried for this purpose, such as wood, iron and vulcanized indian-rubber. The Confederates appear to have used wooden barrels for their smaller charges, and cases of boiler plate iron for their larger mines. The large charge of 1,750lbs., which destroyed the "Commodore Jones," in the James river, and that, of similar size, which so narrowly missed the "Commodore Barney," were both in cases of boiler plate iron; these charges were both fired by electricity. A charge of 5,000lbs. of powder, in an iron boiler, arranged to be fired by electricity, was placed at a distance of 1,500 yards from Fort Sumter at Charleston; at the critical moment, however, it failed to ignite, from some unknown cause, which was probably either a defect in the insulation of the electric cable, or a bad fuze. This charge had been four months under water before any attempt was made to fire it, and the art of testing fuzes and insulation was not then known as it is now.

The following is a description of the construction of the cases

for submarine mines, exhibited by the Austrian War Department, at Paris, in 1867.

Forms of case used by the Austrians.

The form and arrangement of the charge of a gun-cotton mine in a wooden case is shown in the accompanying sketch, *Fig.* 1, *Plate* III, which gives an elevation and section. It consists of two strong wooden cases, one within the other; the inner one covered with zinc, and the space between them filled in with tar. They are of the shape of a truncated cone, but the diameter of the bottom is very slightly greater than that of the top. The outer one has a mean diameter of about 4 feet and is about 4 feet in height; it is calculated to contain 4cwt. of gun-cotton, made up in coils and packed with plenty of air space, as shewn in section *Fig.* 2, *Plate* III; in this section the air space is shewn light. Abel's compressed gun-cotton affords great advantages over that in coils, as employed by the Austrians. The size of a given charge of cotton is thereby reduced, from three times that of powder, to nearly an equal bulk, weight for weight. *Fig.* 3, *Plate* III shows an elevation, and *Fig.* 4, *Plate* III a section of an iron case, calculated to contain about 3cwt. of gunpowder. It consists of an outer cylinder *a* at the top of which is a series of projecting buffers, held in position by strong springs, by pressure against which the circuit from the firing battery, through the fuze, is completed by a vessel passing over the mine. These buffers are shown in the sketch at the points *b,b,b*. Within the outer case a second iron cylinder *c* is placed, to contain the charge of powder, a sufficient air space, to give the requisite buoyancy, being allowed by the difference in size of the cases. The outer case is about 3 ft. 6 in. in diameter and 3 ft. 6 in. in height.

The Austrians now propose to use the iron case shown in *Figs.* 3 *&* 4, *Plate* III only, for submarine service, and no longer employ the wooden case shown in *Figs.* 1 *&* 2. The iron service case is precisely of the same form as that exhibited at Paris in 1867. They also propose to use compressed gun-cotton, fired with a detonating fuze, as their explosive. This latter has not, however, been definitely decided on, in consequence of the serious accident which so lately occurred at Stowmarket. They only await, however, the result of the investigations, in England, into the cause of this disaster, and as these have not shown any serious amount of danger to be incurred in the storage of compressed gun-cotton, when proper precautions have been taken in its manufacture, there is very little doubt that it will ultimately be adopted by them for their submarine mines.

Captain Harding Steward's suggestions, as to the use

Captain Harding Steward, R.E., has suggested placing the charge in an indian-rubber bag, the bag being furnished with an outer covering of iron. This outer covering need not necessarily be water-tight, and is only intended to protect the indian-rubber from injury, by friction against rocks, &c., and to give

PLATE III.

AUSTRIAN CASES FOR SUBMARINE MINES.

Fig. 1

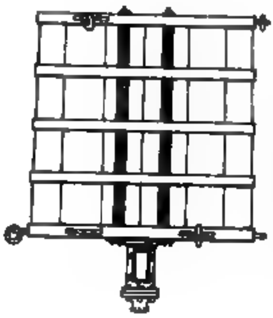


Fig. 2

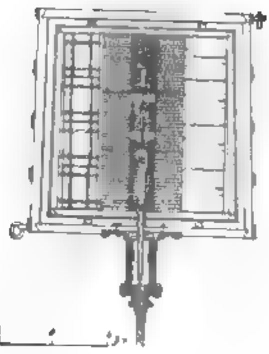


Fig. 3.

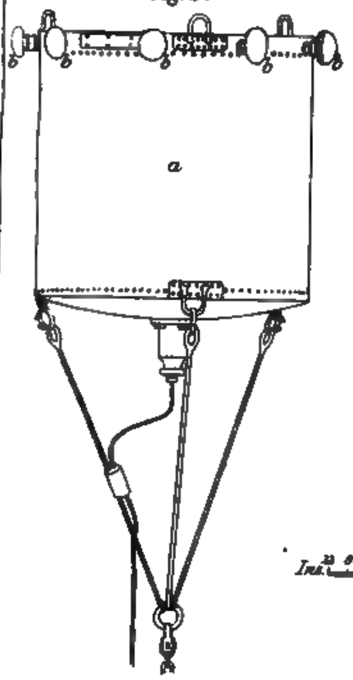
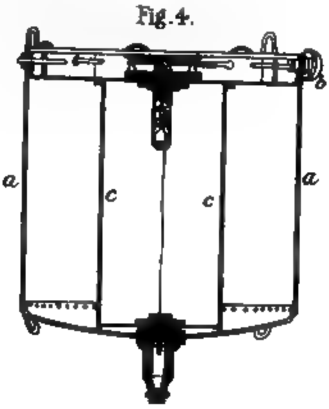


Fig. 4.



Lithographed at the S. M. E. Chatham *B. Butler, Corpl. R. E.*

rigidity to the whole apparatus, so that it may be easily handled and, when required, moored by means of sinkers in the usual way. In some experiments tried by the Confederates, it was found that a large charge of powder, enclosed in an indian-rubber bag, did not produce the same amount of explosive effect, as the same charge in an iron or wooden case of considerable strength. It is probable that the envelope was burst by the first explosion, and a portion of the charge wetted, before the whole of the powder had been ignited, and in order to obviate this result, Captain Steward proposes to ignite the charge at a great many different points, so that the whole may be fired, as it were, simultaneously, and the drowning effect thus partially obviated. This is done by a single fuze, placed at the extremity of a metal tube, passing through the charge, and the tube being perforated at intervals, the flame and gas of a small priming charge is driven into the body of the main charge at a large number of points simultaneously. A more minute description of this arrangement will be given in treating of the several modes of ignition applicable. It is to be remarked that the confederates only used one fuze in their charges, whatever their size might be, and this is quite sufficient to account for the non-ignition of the whole of the powder in a large charge when enclosed in an indian-rubber bag only. The advantages of Captain Steward's system are the comparative cheapness of the case, and that it is not dependent on the iron outer covering for keeping the charge dry; this covering may consequently be made by a comparatively inferior workman.

of indian-rubber bags.

Indian-rubber bags used in connection with operations on Steamer "Foyle."

In removing the wreck of the steamer "Foyle,"* sunk in the Thames at Barking Reach, in 1866, which service was performed by the officers and men under instruction in the School of Submarine Mining, Chatham, during the summer of 1868, the charges were all enclosed in vulcanized indian-rubber bags, within an outer casing of half-inch boiler plate iron. It was intended that the outer iron coverings should have been water-tight, but by some accident one of these cases leaked considerably; the charge was however saved by the indian-rubber bag, and performed its work apparently as well as any of the others. This leak was attributed to the fact that the iron case had been left for some time before it was filled with powder, in a hot sun; in fact the air inside felt very hot to the hand. When subsequently submerged, it was supposed that the cooling and consequent contraction of the air had caused a considerable increase of external pressure, and that the water had forced its way through some weak place. All the iron cases used had been tested by hydraulic pressure, and were apparently sound before immersion, yet the fact of the water having got into the case is indisputable. Assuming that the leak was occasioned by the cause above

* A full description of the operations, against the wreck of the "Foyle," is given in Volume XVIII of the Professional Papers of the Royal Engineers.

Cases should not be loaded or kept in the sun or at a high temperature.

specified, it is necessary to keep iron cases out of the sun and fill them, with the air inside at a temperature somewhat similar to that of the water in which they are to be placed; and again, when it is necessary to store them, especially in positions where they may be subjected to considerable changes of temperature, the screw plug, or man hole, should be left open to allow a free ingress and egress of air. As a matter of precaution, this should be made a general rule whenever it becomes necessary to store these cases: this course is adopted with regard to large iron buoys.

Indian-rubber bags have been successfully used in the demolition of other wrecks since that of the "Foyle." For ordinary submarine operations where compressed gun-cotton, fired with a detonating fuze, is employed as the explosive, and where the charge is of a convenient size for handling with safety, in an indian-rubber bag, and where it is to be fired soon after submersion, there is no doubt that indian-rubber bags, with or without an external iron or other protecting covering, will be found very useful. In all extemporised cases for submarine mines, they are also likely to prove very effective, as by their means the charge may be kept dry even when the outer protecting envelope is not absolutely watertight.

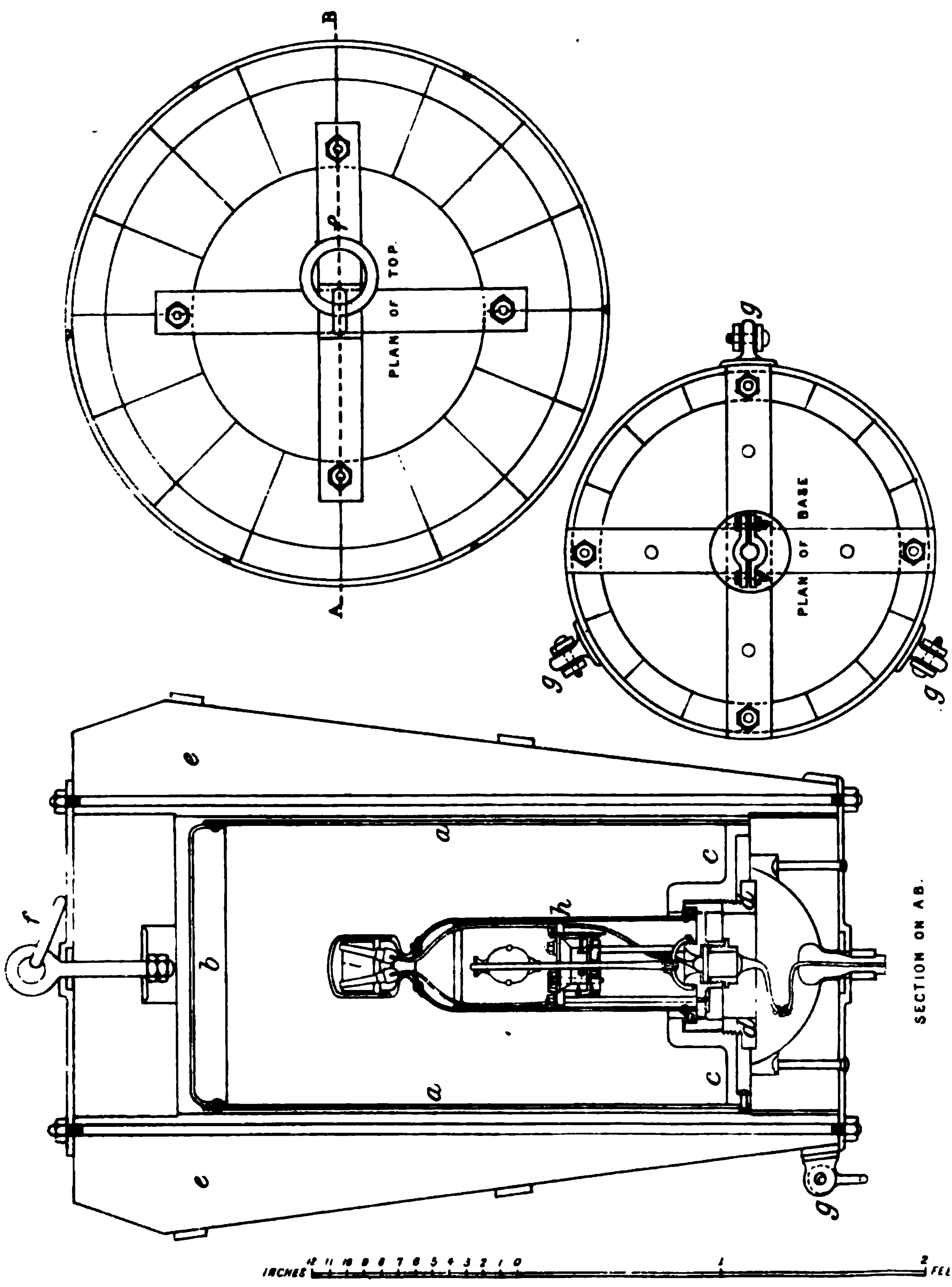
Approved form of case.

After numerous experiments carried on at Chatham, under the direction of the several Committees, which have had the question referred to them, it has been decided to employ wrought iron as the material, and a cylinder as the form, for all cases for submarine mining service; and cases to contain charges of compressed gun-cotton of the following sizes have been approved, viz:—100lbs., 250lbs., 500lbs., and 1000lbs.

100lb. case: construction and dimensions.

The general design and dimensions of the 100lb. case are shown in section in *Plate* IV. It consists of a wrought iron cylinder *a* of No. 12 B. W. G. iron plate, riveted; the upper end *b* to be slightly dished and of the same thickness of metal; *c* is the base piece, riveted directly to the cylindrical iron plate of the body; the opening in this is circular, 6 inches in diameter, of the same dimensions as those for all classes of cases, and serves as a loading hole and for the introduction of a circuit closer of Mathieson's form, which is arranged to be placed within the case; *d* is a screw piece to keep everything watertight. The case being made of such thin metal, for the sake of lightness, it is necessary to tin it, in order that the joints and rivets may be thoroughly watertight. In carrying out the tinning process, each case is immersed in diluted hydrochloric acid for 24 hours, to clean the surface, after which it is dipped in an amalgam of 75 parts of tin and 25 of lead. After being tinned it should be tested by a gradually increasing pressure from within up to 15lbs. on the square inch, this maximum pressure being kept up continuously for a short interval, not less than 15 minutes. A case which stands this test without

ELECTRO-CONTACT MINE FOR 100 LBS. GUNCOTTON.
SHOWING JACKET, CASE AND CIRCUIT CLOSER.



Lithographed at the S.M.E. Chatham.

B. Butler, Corpl. R.

showing any symptoms of leakage, may be pronounced fit for service. These cases are designed for use at comparatively small depths of water, for example in positions where they would be just covered at low water, but would have to resist the pressure due to the full rise of the tide. This might amount, in certain cases, to as much as 30 feet, a depth which—at extreme high water—would place the 100lb. charge at a disadvantage; considering also that they are intended to act against gunboats and vessels of small draft of water, it would be necessary, where the rise and fall of the tide is more than 20 feet, to moor them with such a length of cable as to leave them a-wash at half or three-quarters full tide. *e* is a wooden jacket of yellow pine, slightly conical in form, to protect the iron cylinder from injury when subjected to blows from friendly, passing ships. This jacket is built up of any convenient number of segments, between 9 and 18, running its entire length, cemented together with marine glue, turned all over and bound at the top, centre and bottom with wrought iron hoops; the whole is placed under a hydraulic press, and submitted to a pressure of 2,800lbs. on the square inch, so as to ensure the joints fitting closely together. The top and bottom of the case are secured by iron cross plates, connected at their extremities by four longitudinal iron bolts. It is a great object to exclude the water from penetrating into the woodwork, so as to retain, as far as possible, the buoyancy due to the small specific gravity of the wood: with this object in view, experiments are now being tried, by soaking each section of the wood in creosote; these experiments promise very well, and though the system of creosoting has not yet been definitely decided on, it is probable that it may be ultimately adopted. The present mode of protection against the penetration of water is by a mixture of pitch and tar well burnt on: should creosoting be adopted, the protection of pitch and tar will continue to be applied in addition thereto. With this protection the wooden jacket should continue to retain its buoyancy for several months, when immersed in water of varying depths up to a maximum of 30 feet.

Jacket for electro-contact mine.

The case is intended essentially for a contact charge and a maximum of buoyancy is absolutely necessary. The wooden jacket is provided with a ring *f* at the top, from which to suspend the case, and with three rings *g*, to receive the shackles for attachment of the mooring chains.

Circuit closer.

The circuit closer *h* fits within the charge, and is contained in a sheet copper dome, of No. 19, B. W. G., screwed on to a cast iron base, and with an arrangement for the attachment of the electric fuzes and gun-cotton priming *i*. The circuit closer is of Mathieson's form, the details of which shall be described hereafter.

The iron case, without its wooden jacket, when loaded with its 100lb. charge and circuit closer, is just buoyant: when encased

in its jacket, and with 35 feet of electric cable and its attachment chains, it has a buoyancy of about 140lbs.

250lb. case: construction and dimensions.

The general design and dimensions of the 250lb. case are shown in section in *Fig.* 1, *Plate* V. The body consists of $\frac{3}{16}''$ Low Moor iron plate, or iron of similar quality, riveted, with dished ends. The size and construction of the mouth piece is similar to that of the 100lb. case, so that the mouth pieces, fuze pieces, &c., may be interchangeable. The whole of the iron work should be painted two coats, and tested to a pressure of 30lbs. on the square inch, gradually increasing from within. The mooring chains are attached by eyes of the form shown in *Fig.* 2, to wrought iron bands screwed to the body by coupling screws. The charge of 250lbs. renders it applicable for the destruction of a vessel without absolute contact; it may however be necessary, in certain cases, to employ it as a contact mine, and when used as such a wooden jacket must be added, to protect the case from injury by collision with friendly vessels. Its calculated weight, complete with charge, is about 520lbs. *Fig.* 3, shows a plan of the bottom of this case, with mouth piece, &c.

In order to convert this case into a buoyant mine, additional floatation must be given by the attachment of buoyant bodies thereto. The amount of floatation to be added would involve conditions, dependent on the length of mooring cable necessary and the velocity of the current in which the mine is to be placed. The wooden jacket adds to a certain extent to the buoyancy, but it must be borne in mind that, even with every precaution, the wood becomes more or less saturated after submersion for any considerable time, and only half the buoyancy due to this outer casing should, on this account, be included, in calculating for the floatation to be given under any particular circumstances.

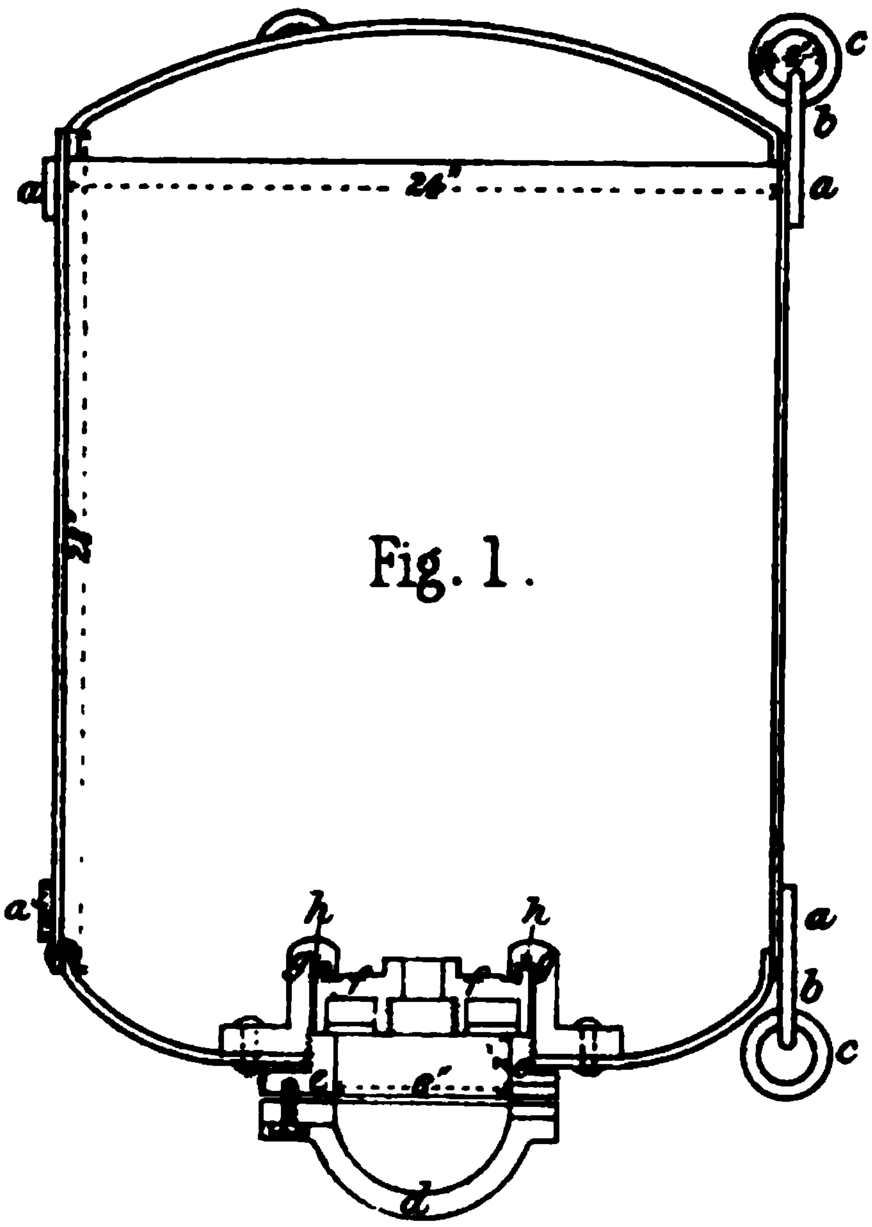
In *Plate* V., *a*, *a*, are wrought iron bands, carrying lugs *b*, *b*, with rings *c*, *c*, for the attachment of the mooring chains; *d* is an iron dome to protect the electric cables, at their entrance into the mouth piece; *e* is a screw collar for tightening up the mouth piece, *f* the mouth piece itself, *g* the cast iron mouth of the case, with shoulder to receive the mouth piece; *h*, *h*, are washers to make the whole watertight.

500lb. case: construction and dimensions for a ground charge.

The general design and dimensions of the 500lb. case are shown in section in *Fig.* 1, *Plate* VI. The body is formed of $\frac{1}{4}$-inch Low Moor iron plate, or iron of similar quality. The ends are dished, and the mouth piece and arrangement for attachment of the moorings are precisely similar in form to that of the 250lb. case. The whole of the iron work should be painted two coats; the case should be tested to a pressure of 40lbs. on the square inch, gradually increasing from within. The calculated weight of the case, with charge complete, is about 1,000lbs.; this exceeds the total buoyancy by about 190lbs.; it has therefore no floating

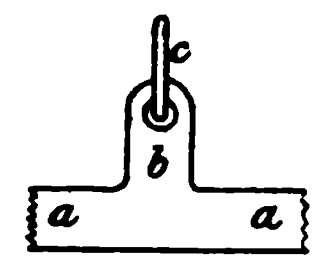
CASE FOR 250 LB. GUN-COTTON MINE.

Fig. 1.



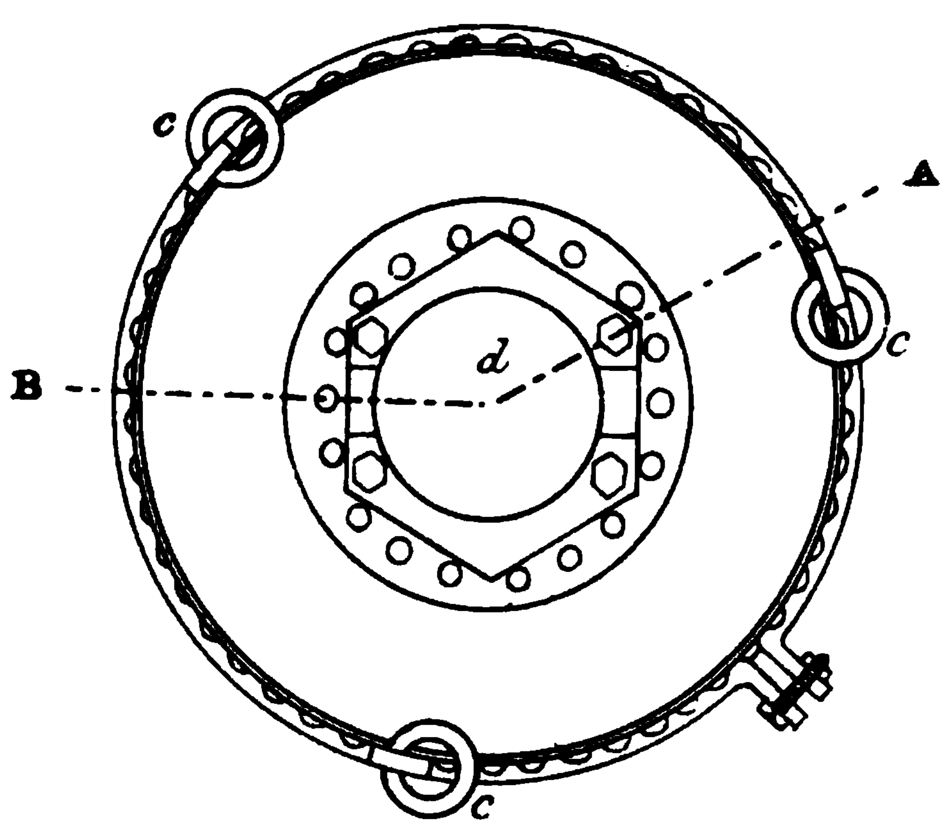
SECTION ON AB.

Fig. 2.



ELEVATION OF LUG.

Fig. 3.



PLAN OF BOTTOM.

Lithographed at the S. M. E. Chatham. *B. Butler. Corp.l R. E.*

CASE FOR 500 LB. GUN-COTTON MINE.

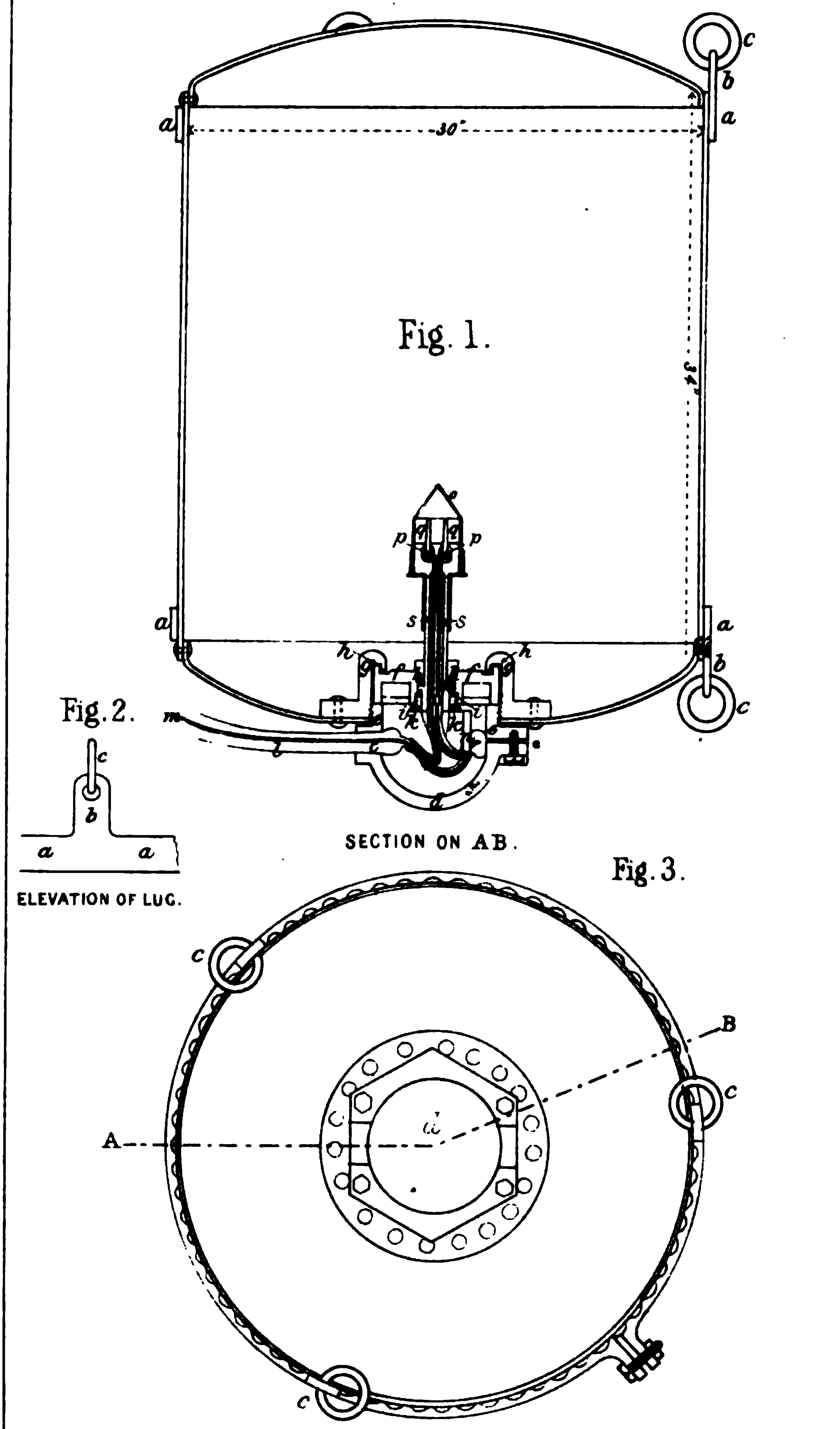


Fig. 1.

SECTION ON AB.

Fig. 2.

ELEVATION OF LUG.

Fig. 3.

PLAN OF BOTTOM.

Lithographed at the S. M. E. Chatham. *B. Butler. Corpl R. E.*

power, and if required to be floated up from the bottom, the necessary buoyancy must be attached.

In *Plate* VI., *a*, *a*, are wrought iron bands, carrying lugs *b*, *b*, with rings *c*, *c*, for the attachment of the mooring chains; *d* is an iron dome to protect the electric cables at their entrance into the mouth piece; *e* is a screw collar for tightening up the mouth piece, *f* the mouth piece itself, *g* the cast iron mouth of the case, with shoulder to receive the mouth piece; *h*, *h*, are washers to make the whole watertight. The whole of the fitments of the mouth piece, fuze piece, &c., are of the same dimensions for every size of case, so that they may be interchangeable. These are shown in *Plate* VI. as follows:—*i* is the ebonite fuze piece; *k* the hexagonal union for fuze piece; *l* the armoured electric cable; *m* the insulated core; *n* the earth plate; *o* the zinc guard, covering the detonating fuzes *p*, *p*, and the priming disc *q*, of gun-cotton; *s* is the insulating composition, round the conducting wires of the fuze piece; *t* the opening between the dome and the screw collar, for the admission of the electric cable. This shows the general arrangement of this important part of the case. The details of the fuze piece, mouth piece, &c., shall be more minutely described hereafter.

500lb. case: construction and dimensions for buoyant mines.

Where there is a considerable depth of water, of 10 fathoms and upwards, for example, it would be necessary, to provide buoyant mines of the 500lb. size. In order to meet this contingency, a special case for a buoyant 500lb. charge has been provided. This only differs in construction from that shown in *Plate* VI., in being made of 3-16th inch Low Moor boiler plate iron, or iron of equal quality, instead of ¼-inch; the dimensions of the case, exclusive of the dish of the top and bottom, being 32½ inches long and 31 inches in diameter; such a case, when loaded with its charge of 500lbs. of gun-cotton, would have a buoyancy of about 220lbs., this would be reduced to about 170lbs. by the weight of the attachment chains and electric cable. The test pressure for such a case would be up to 30lbs. on the square inch, gradually increasing from within.

1000lb. case: construction and dimensions.

No definite pattern of case to contain a charge of 1,000lbs. has yet been made; it should however be similar in form to the 500lb. case, and be composed of ½-inch Low Moor iron plate, or iron of similar quality, and of such cubic space as to contain the requisite charge, viz:—33 inches in diameter, by 40 inches long, not including the dish of the ends. The mouth piece should be the same as before, in order that the fuze pieces, &c., may be interchangeable; the attachments for the moorings should be similar to those of the 500lb. case, but of proportionately larger dimensions.

Above dimensions calculated

The dimensions of all these cases are calculated for compressed gun-cotton, and their thickness is not sufficient to develop the maximum explosive force of gunpowder; if therefore this latter

for compressed gun-cotton.

explosive be used, detonating fuzes and several centres of ignition must be employed. The cubic space occupied by a given charge of gunpowder is slightly less than that required for an equal weight of compressed gun-cotton; for practical purposes, however, the cases described may be taken as the same for both.

The following data will be found useful in calculating the displacement, weight, available buoyancy or floatation, collapsing pressure and bursting pressure of any given mine:—

Displacement.

1st, as regards the displacement. Find the area of the case in cubic feet; in the cylindrical form used for service, the dishing of the ends may be disregarded or roughly included by adding an inch or two to the length. Fresh water weighs 62·425lbs. and salt water 64·05lbs. per cubic foot. If, therefore, the area in cubic feet be multiplied by either of these numbers, the displacement of any given mine in fresh or salt water is easily calculated.

Weight.

2nd, as regards the weight. The following weights, extracted from *Rankine's Applied Mechanics*, afford an easy means of calculating the weight of any given case—

½-inch wrought iron plate weighs	20lbs.	per square foot.	
¼ " " " " "	10	"	"
3-16 " " " " "	7·5	"	"
1-16 " " " " "	2·5	"	"
No. 12, B. W. G., " " "	4·4	"	"
" 11, " " " "	5·	"	"
" 10, " " " "	5·5	"	"

If therefore the superficial area of the case be found in square feet, its weight may readily be calculated, by multiplying by the figures given above, corresponding to the thickness of the metal. The weight of the mouth piece, disc, &c., must be added, calculated at ·27lbs. per cubic inch.

Floatation.

3rd, as regards the floatation. The weight complete, including the charge, having been ascertained it is only necessary to deduct it from the displacement, previously ascertained, to find the amount of floatation, or available buoyancy in fresh or salt water as may be required.

Collapsing pressure.

4th, to find the collapsing pressure, the following formula, from *Rankine's Applied Mechanics*, may be used, where the form of the case is cylindrical:

$$q = 9{,}672{,}000 \frac{t^2}{l.d}$$

where $q =$ the collapsing pressure in lbs. on the square inch; $t =$ the thickness of the iron plate in inches; $d =$ the external diameter of the cylinder in inches; and $l =$ the length of the cylinder in inches.

Bursting pressure.

5th, the bursting pressure may be found from the following

formula, from *Rankine's Applied Mechanics*, when the form of the case is cylindrical:

$$p = \frac{t.f}{r}$$

where p = the bursting pressure in lbs. on the square inch, applied from the inside; t = the thickness of the plate in inches; f = the tenacity in lbs. per square inch; and r the radius of the cylinder in inches. The tenacity f of wrought iron may be taken at 34,000lbs. per square inch, according to *Rankine's Applied Mechanics.*

Result of experiments, on strength of case, by Floating Obstruction Committee.

A good many experiments have been tried by the Floating Obstruction Committee, to ascertain the requisite strength of case to fulfil the necessary conditions already enumerated, and the following result of their investigations, when gunpowder, fired with an ordinary fuze, is the explosive, is extracted from their published report:—

"These experiments lead to the general conclusion that the effect of a charge of gunpowder, exploded under water, is enhanced in a very great degree by the strength of the case in which it is enclosed, seeing that even with so small a charge as 4lbs. the maximum effect of the force is not attained until a case is provided of $\frac{1}{8}$-inch iron, and which will stand a gradual pressure from within of 330lbs. per square inch.

"It may therefore be assumed that the manageability of a charge will alone determine the maximum weight or strength to be given to a torpedo, and that all the strength which it may be found necessary to give to the case, in order to resist the pressure of the column of water under which it is submerged, will tend to increase the effectiveness of the charge, there being no risk that such extra strength of case will involve an expenditure of force, in its rupture, at all approaching in extent to the advantage gained by its resistance, and the consequent increase of time afforded for the development of the explosive force of the charge."

A corroboration of this opinion appears in the account of the experiments on board the "Excellent," where the effect of $5\frac{1}{2}$lbs. of powder in a shell, approximated to that of 25lbs. in a barricoe.

Effect of a given charge against the bottom of an ironclad.

Though we have thus come to a decision as to the sizes of charges to be used, and the nature and dimensions of the cases to contain them, we do not yet know what the effect of these charges against the bottom of a modern ironclad would be, and it is of the utmost importance that this essential information should be determined by practical experiment. The sizes of the charges chosen, have been derived from the results of experiments with small charges, tried against targets of various forms, but an experiment on a large scale is absolutely necessary.

Barrels may be used as a makeshift.

In all cases the most approved form of envelope, to contain a charge of powder for submarine mining purposes, may not always be at hand, and it may be necessary to use ordinary barrels or any

other available articles. Barrels are very readily obtained everywhere and, when properly strengthened, are a tolerable substitute for the more approved form of case; they are moreover made of sufficient size to contain a considerable charge of powder.

In blowing up wrecks in the river Hoogly, as reported by Lieutenant Wallace, R.E., in Volume XVI. of the Professional Papers of the Royal Engineers, page 116, barrels were used. These were of different sizes, viz., hogsheads, half-barrels, and kilderkins, holding respectively 500, 300, and 150lbs. of powder. Lieutenant Wallace tried several methods for strengthening the two larger sizes, which he found necessary, and that employed by Sir Charles Pasley, in his operations upon the wreck of the "Royal George," and shown in *Figs.* 1 & 2, *Plate* VII., was found to be the most effectual; it consists in strengthening the ends of the barrels with wood. The projecting tops of the staves of the original barrel were cut half away, and the strengthening of wood arranged to break joint with them, while at the same time filling up the spaces cut away. This done the barrel was well payed over with pitch and tar and, when required to remain a considerable time under water, the whole was sewn up in a stout canvass covering, also well saturated with the same composition of pitch and tar. Lieutenant Wallace found that, in a strong tideway, a charge of 500lbs. of powder required a weight of 400lbs. to sink it, whereas in slack water less than half that weight was sufficient. When used as makeshifts, barrels should in all cases be strengthened, by binding them tightly round with hoop iron.

All cases must be very watertight.

As in submarine mines the charges must generally remain a considerable time under water before explosion, it is most necessary to make the case, whatever it may be, very watertight, and with this view the inside of a barrel might be lined with a coating of marine glue or cement. In the experiments carried on by the Floating Obstruction Committee, the latter was found to give a perceptible increase of explosive effect, when used as an external coating to XX tin cases for small charges, by giving an increase of time for ignition. An internal case of XX tin would in many instances prove a very effective means of keeping the charge dry. In using it care should be taken to fix it firmly inside the barrel, as any independent motion might disturb the connections of the electrical conducting wire or destroy its insulation. An internal indian-rubber bag, as recommended by Captain Harding Steward, placed inside a barrel would also afford a ready means of preserving the charge in a dry state.

An internal tin case or indian-rubber bag recommended to keep charge dry.

If greater floatation than that afforded by the barrel, when loaded, is required, in order to fit it for a buoyant mine, it must be obtained by buoys or corks attached to it.

A steam boiler a good makeshift.

Another makeshift which may be used for submarine mining purposes is a steam boiler; and any other envelope presenting the

MODE OF STRENGTHENING BARRELS.

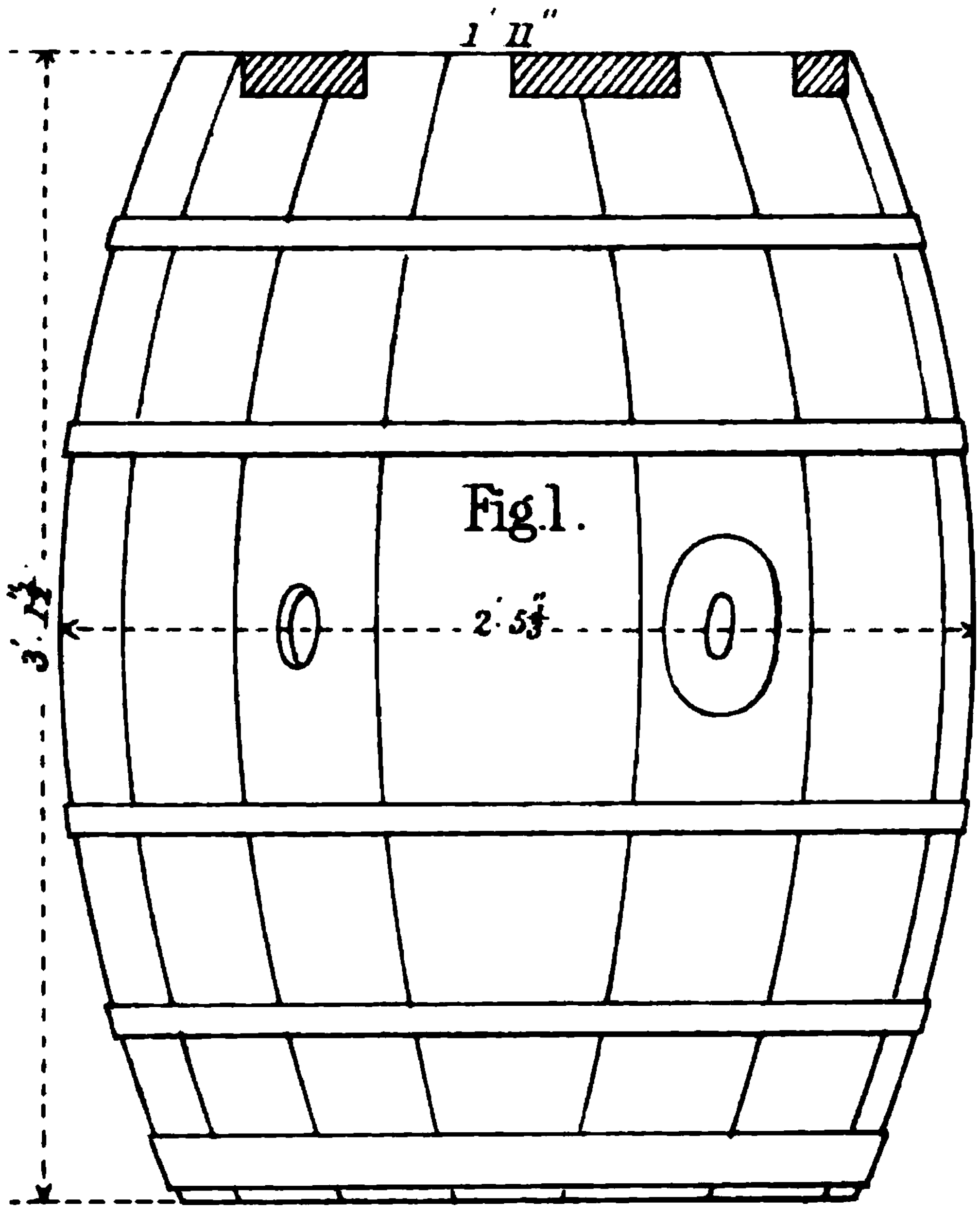


Fig.1.

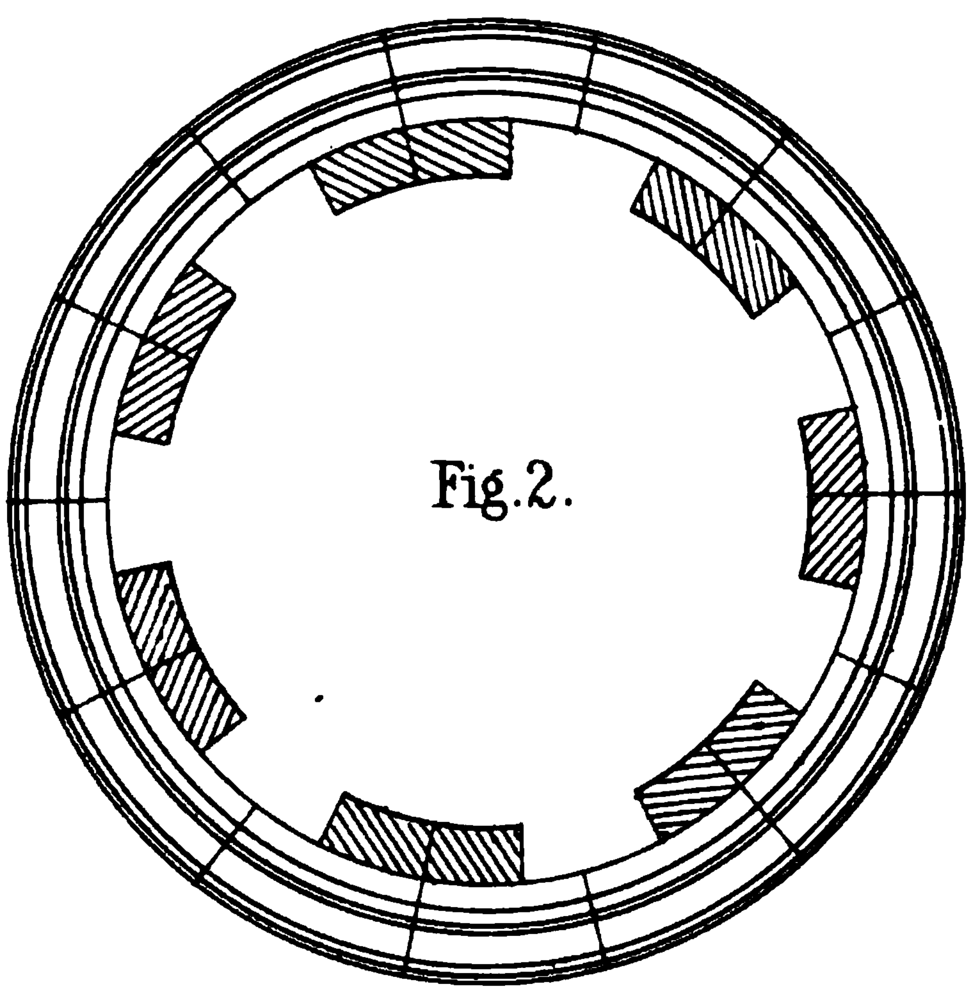
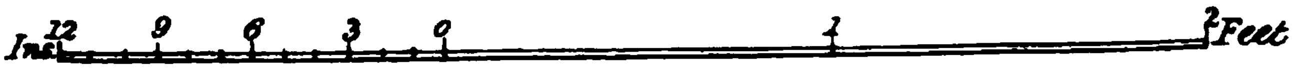


Fig.2.



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necessary requisites of strength, to resist the external and bursting pressure at the moment of ignition, in a sufficient degree to ensure a good explosive effect, and also possessing the property of being very watertight, would answer the purpose. In all cases it would be necessary to use the same precautions, in the preparations of these articles, as recommended for the barrels, and which indeed are the essential points to be attained in any envelope for submarine mining purposes, whether of a makeshift character or constructed especially for the purpose.

A strong case essential with gunpowder or gun-cotton, fired with an ordinary fuze—with gun-cotton fired with a detonating fuze it is not so essential.

These remarks, with respect to the strength of case necessary to develop the explosive effect of any given charge, have reference especially to gunpowder; and as circumstances may occur in which gunpowder alone is obtainable, they must not be omitted in considering the organization of any system of submarine mines. If any other explosive be used, the necessity for employing a case of sufficient strength, with reference to the peculiarities of that explosive, must still be kept in view. Compressed gun-cotton fired with an ordinary or with a detonating fuze is the most likely agent to be employed. If fired with the ordinary fuze it would still be necessary to take the strength of case, to develop the full explosive effect of the charge, into consideration, and the conditions would be very similar to those of gunpowder, bearing in mind that, where an equivalent only is used, a case of proportionately smaller size will be sufficient. If fired with a detonating fuze, we may omit the consideration of the strength of the case as far as the development of the explosive effect of the charge is concerned. The other conditions to be fulfilled, viz., capacity to keep out water, sufficient strength to bear handling without danger of fracture, &c., enumerated in the beginning of this chapter must, however, be kept in view.

Compressed gun-cotton adopted for service.

Compressed gun-cotton fired with a detonating fuze has been adopted as our explosive for submarine mining purposes, and the service cases described are adapted for it.

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CHAPTER V.

Mooring.

The next point to be considered is the mode of mooring a submarine mine, when it is to be floated up from the bottom, as well as when actually laid on it.

The question of mooring seems at first sight a very simple matter, practically, however, it has been found to be one of the most difficult problems to be solved in connection with a system of submarine mines. In order to possess a maximum of efficiency no indication of the position of a mine should appear on the surface of the water,* and yet the spot, to within a few feet, where it is deposited must be known to the defenders of the position in which it is used. It has been found that the least current, or even a moderate breeze, renders the placing of even a single mine in a definite position, a matter of very considerable difficulty; when a series of mines is to be moored in proper relative position this difficulty is much increased, and it is again considerably augmented in proportion to the depth of the water. Under certain conditions, therefore, special means, to be hereafter described, must be employed.

Objects to be attained.

The objects to be attained in mooring a buoyant charge are as follows :—

1st. That the charge should be kept as nearly as possible stationary at the point where it is required to act. This is particularly necessary where there is a tide which, flowing first in one direction and then in another, tends to cause the mine to shift its position; it is indispensable in the case of mines to be fired by judgment.

2nd. The moorings should be so arranged that there shall be as little twisting as possible, which might break or injure the insulation of the electric cable.

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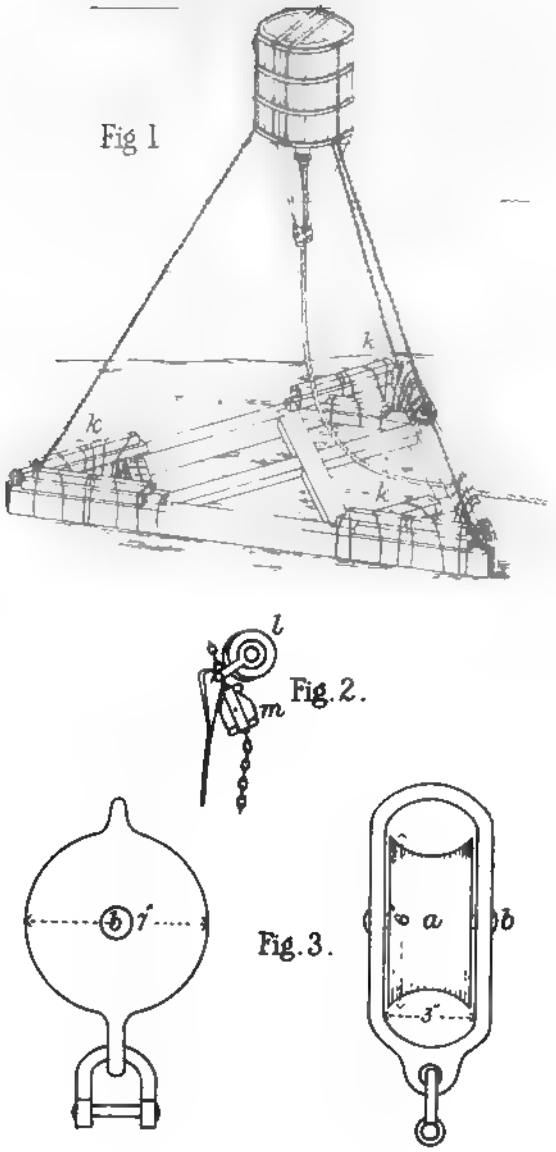
* In certain cases it is impossible totally to conceal the position of a system of mines, as for example, when there is a considerable rise and fall of the tide. When such is the case, the very smallest indication possible should be allowed to appear on the surface of the water.

PLATE VIII.

AUSTRIAN MOORING APPARATUS.



Lithographed at the S. M. E. Chatham

B. Butler, Corpl. R. E.

3rd. The anchors or heavy weights used should be suited to the nature of the holding ground or bottom.

4th. Mooring cables should be so arranged that they may not be likely to become twisted together or entangled.

Buoyant submarine mines may be moored by one or more cables according to the different circumstances of the case, and several modes of mooring have been suggested and adopted.

Austrian mode of mooring.

The following is a description of that used by the Austrians during the war in 1866, and exhibited by them at Paris in 1867.

In the Adriatic, where there is almost no tide or current to disturb submarine mines or cause them to revolve and twist up their mooring chains, a very simple arrangement for keeping them in their required positions has been found effectual. This is shown in *Plate* VIII., *Fig.* 1, which gives the form employed with the original gun-cotton charges which were designed to be fired at will. It consists of a simple wooden platform of triangular form, on which heavy weights, marked *k*, are placed at intervals; this platform is attached to the submarine mine by three wire ropes, in connection with its angles, which are fastened to three chains holding the charge at any required depth below the surface of the water, by means of a self-acting arrangement shown in *Plate* VIII., *Fig.* 2. This consists of a pulley *l*, attached to the extremity of each of the wire ropes from the angles of the platform, through which the mooring chain of the charge is passed and fastened at the required length, by means of a self-acting key marked *m*, shown in detail in *Plate* IX., *Fig.* 1. This key is of considerable weight, and consequently slips down as the charge is hauled into its place, but the moment the chain is slackened the two arms *a*, *a*, shown in dots, which are made to allow the latter to pass through in one direction only, catch into a link of the chain and hold the charge firmly in its place. The apparatus is so constructed as to allow the chain to be passed freely through it and is provided with nuts to admit of its being separated, in order to disconnect it from the chain when required. In our mooring operations an experimental apparatus of this nature weighing 60½lbs. has been used, in connection with a half-inch chain, with good results. This mode of mooring, by means of three chains attached to the angles of the triangular platform, is said to have been quite effectual in the still water of the harbours of the Adriatic.

Austrian catch.

Austrian mushroom sinker.

In connection with the electro-self-acting, submarine mines more recently adapted, a mushroom sinker has, however, been used; it has been found to answer every purpose and to be less complicated. The weight of the mushroom sinker, adopted by the Austrians is about 3,500lbs., the buoyancy of the charge being about 500lbs.

Block and pulley.

The details of the block and pulley used for experiment at the

School of Military Engineering, Chatham, in connection with this key, are shown in *Plate* VIII., *Fig*. 3. The sheave *a* is made of cast iron, galvanized, and the remainder of wrought iron. The sheave *a* and axle *b* were, in the first instance, made of gun metal, but the electrical action, set up between this and the iron, of which the remainder was constructed, had the effect of decomposing the latter very rapidly, and the apparatus in consequence soon became useless. Experience teaches us that no two metals, between which electrical action is likely to occur, should be placed in contact in sea water, as the latter is quite sufficient to induce voltaic action, to the detriment of one of the component parts, and destroy the apparatus. An ordinary shackle is attached to the block to enable it to be fastened into a link of a chain or thimble when requ'red; when convenient it may be fastened directly into the eye of the mushroom sinker, which under certain conditions would simplify the arrangements very much. The dimensions shown are adapted for a ½-inch chain. When new it works very well, but rust soon renders it stiff.

Metals between which electrical action occurs not to be placed in contact in sea water.

Barbed catch.

Plate IX., *Fig*. 2 shows another description of catch by which a charge, which has been hauled down, may be held in its place. It consists of a simple pair of barbs, *b*, *b* working on an axle and held open by an indian-rubber spring *a*, *a* capable of being compressed; if pushed away from the indian-rubber they simply press against each other, shoulders being provided on each, close to the axle, to sustain any pressure exerted against them. To use this apparatus it is only necessary, after measuring the depth of water at the point where the mine is to be submerged, to insert the catch at the required distance on the mooring cable below the charge, and haul down through a thimble or eye on the mushroom sinker or moorings, when the mine will be retained at the required depth below the surface.

It possesses the advantage over the Austrian arrangement, *Fig*, 2, *Plate* VIII., that it can be used in connection with a hemp or wire cable, whereas the Austrian can only be used with a chain.

Catches of this kind have been used in our mooring practice with very good results when new. When they have been some time submerged the rust makes the joints very stiff and they then become hard to pull through the ring or thimble in connection with them. The Austrian catch possesses the same defect, becoming very stiff from rust, in fact any iron apparatus must necessarily be injured in this way, and, for the reasons already specified gun metal is inadmissible in close proximity to iron. The rusting is not perhaps of any great importance as, when once hauled down into position, a mine would seldom be required to be moved.

A series of experiments in mooring were carried on at Chatham during the Autumn of 1867, and the following extracts from the

KEYS OR CATCHES, FOR HAULING DOWN APPARATUS.

Fig. 1.

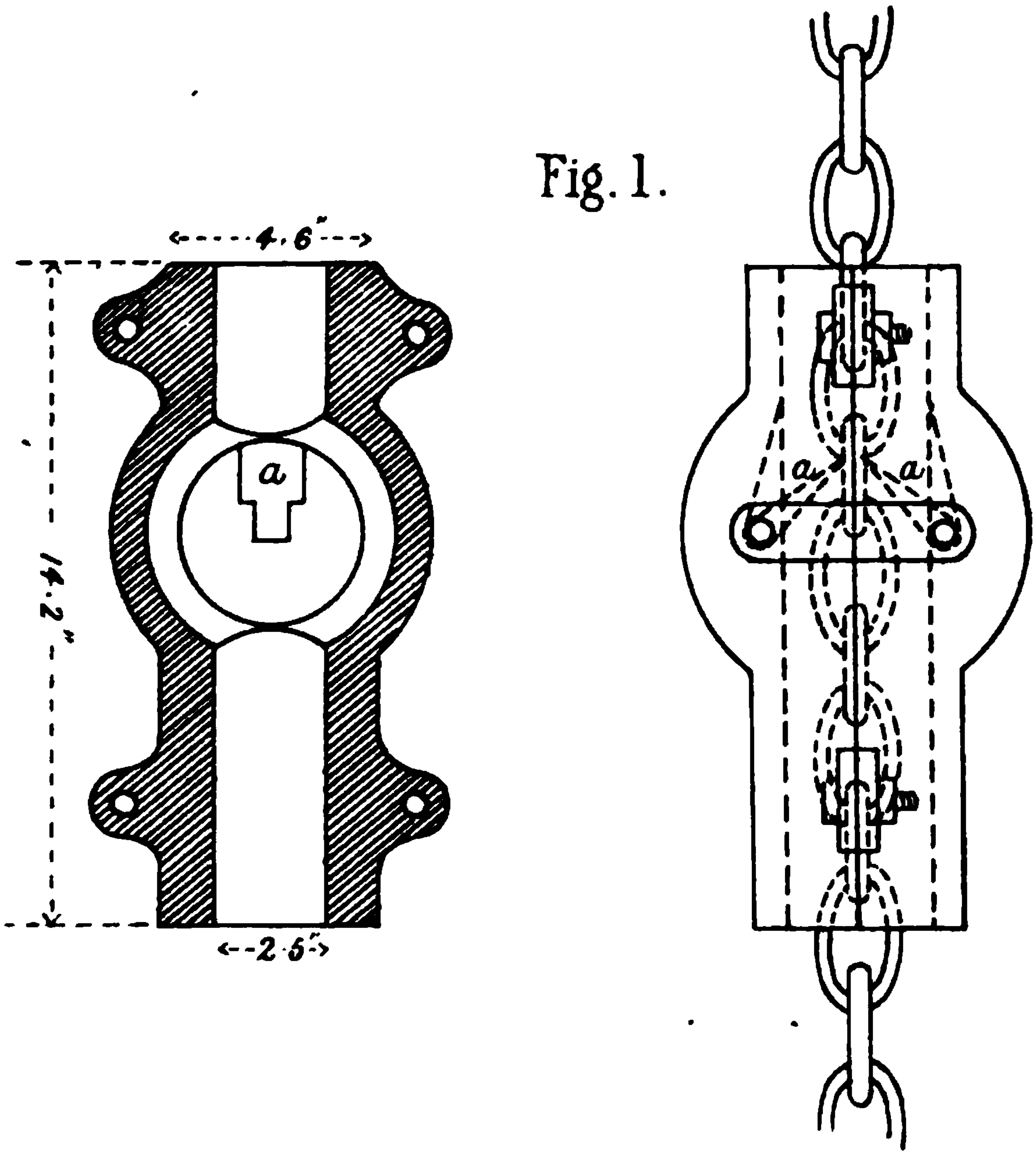
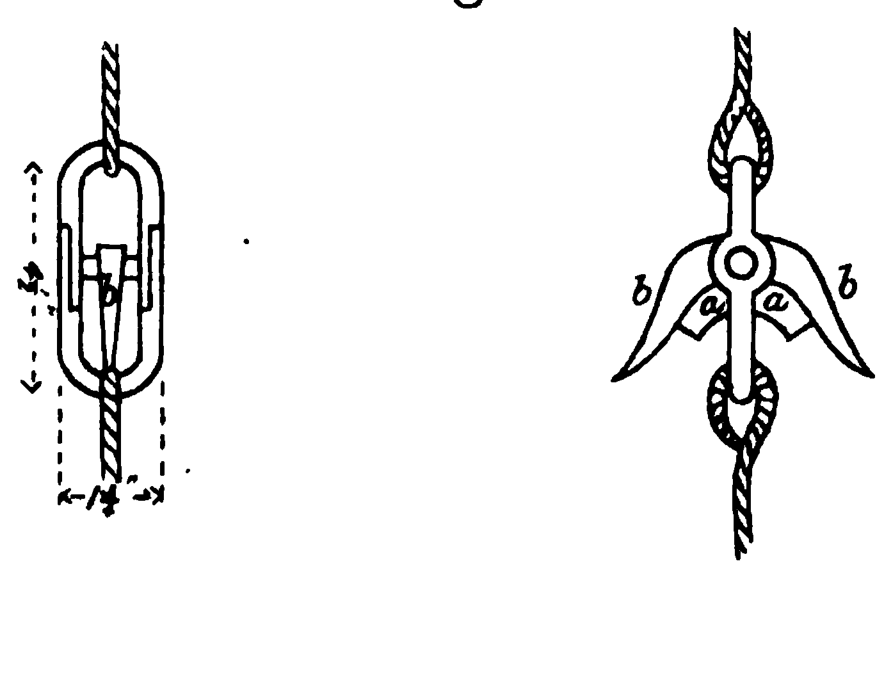


Fig. 2.



Lithographed at the S M E. Chatham.

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PLATE X.

EXPERIMENTAL MOORING ARRANGEMENTS

Fig. 1.

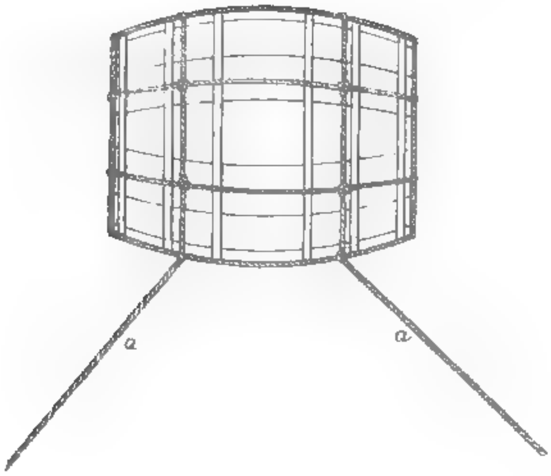
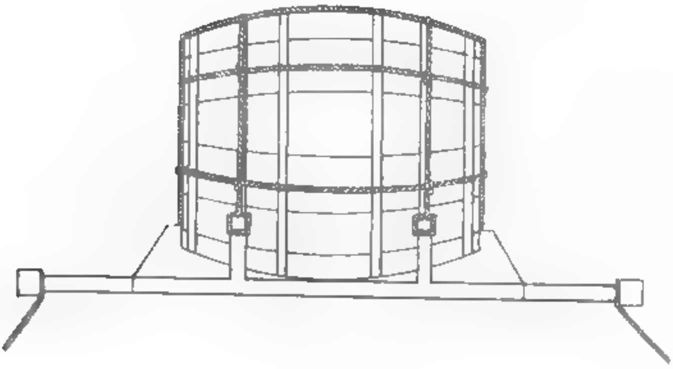


Fig. 2.



Lithographed at the S M E Chatham. *B Butler, Corp! R. E.*

reports of Lieut. O. Chadwick, R.E., who had immediate charge of these experiments, throw some light on the difficulties to be encountered in submerging charges. Though we have not finally adopted Lieutenant Chadwick's views, the record of the experiments undertaken by him is interesting, as showing how our experience, finally culminating in an approved practical system, has been gained.

Experiments in mooring in Medway, near Upnor Castle.

"When the depth of water is so great that a submarine mine, if placed on the bottom, would require for efficiency, an excessively large charge, it must be floated up from the moorings to which it is attached. This introduces great complication in the arrangements and also increased chance of derangement, either by accident or by the operations of the enemy. For still, tideless waters, the Austrian method would no doubt answer. In any current however, the case would be liable to spin round and entangle the conducting wire with the moorings and produce kinks in these, unless indeed the size of the triangle were inconveniently large. It is also easily grappled and taken up, indeed one placed in the Medway at Upnor was, after a few hours, hooked by an anchor of a barge or steamer and carried away."

Faulty arrangement of mooring cables.

While on the subject of methods of mooring when there is any current, the following must be avoided. *Plate* X., *Fig.* 1, shows an ordinary cask with two mooring cables *a*, *a* underneath. The object of using two cables is to keep the mine in a perfectly stationary position, but our experience, derived from experiments carried on in the Medway, is that, unless the attachments of these cables to that mine are kept well apart, they are certain to become twisted round each other when there is a current, and especially in a tideway where it runs first in one direction and then in another. It is clear too that if, in the process of lowering or by any other chance, the mooring cables got a single turn round each other, the effect of their having been originally arranged apart is completely lost and they become as free to revolve as if both cables had been attached to the same point. Practically it was found that with a current of about three knots an hour, as in the Medway, barrels arranged as in *Plate* X., *Fig.* 1, invariably became twisted up in such a way, that an electric conducting wire, connected with the mines to which they were attached, would inevitably have been much kinked and probably injured.

Small charge moored on a spar.

To obviate such a result, Lieutenant Chadwick proposed, for small charges contained in barrels and at moderate depths of water, to lash the mine on a spar, on which a rough framework to fit the form of the barrel had been arranged, and attach the mooring cables to the extremities of that spar as shown in *Plate* X., *Fig.* 2, thus securing the necessary distance between the points of attachment to prevent the chance of entanglement. In order still further to secure this, the anchors, to which the cables are attached, should be placed well apart and plenty of buoyancy allowed to keep the cables tight.

Ladder moorings.

In certain positions it may be inconvenient to place the anchors far apart, and when this is the case, a ladder arrangement may be effectively used.

Plate XI. shows a combination of this sort, somewhat similar to that tried in connection with experiments on board H. M. S. "Cambridge."

The following report by Mr. Charles Cockran, Gunner, Royal Navy, extracted from the *Report of the Committee on Floating Obstructions*, published in 1868, gives the results obtained.

"A buoyant torpedo, consisting of a 27 gallon iron oil-cask, containing 15 gallons of water, and a strongly buoyant nun buoy to represent the circuit closer, were fitted with two mooring ropes from the circuit closer to the torpedo and thence to the mooring ballast, the ropes being separated by wooden rounds or spreaders, from one to three feet long, to resist the tendency to twist. This arrangement, with two insulated wires connecting it with the electric battery, was placed in position on the 18th of April, 1868, in 10 fathoms of water in a part of the Hamoaze liable to strong eddy tides; and at the end of 24 days it was removed. Whilst it was in position the arrangement was twice examined by divers, who reported the mooring ropes and conducting wires to be clear of turns; when taken up, a round turn was found in the mooring ropes close to the ballast, but the whole of the upper portion of the ropes and the insulated wires were clear. This means of employing hemp rope, in the absence of wire rope, in a manner calculated to resist the revolving tendency of the circuit closer, appears to have proved successful. It is, however, to be observed that the rounds or spreaders are liable to lodgments of sea weed or other objects, which might sink the circuit closer; and that the plan does not therefore recommend itself for adoption, except when wire rope is not procurable.

"The buoy rope, which had been attached to the ballast for its recovery after experiment, repeatedly took several turns round the mooring ropes, though cleared by the divers at each examination."

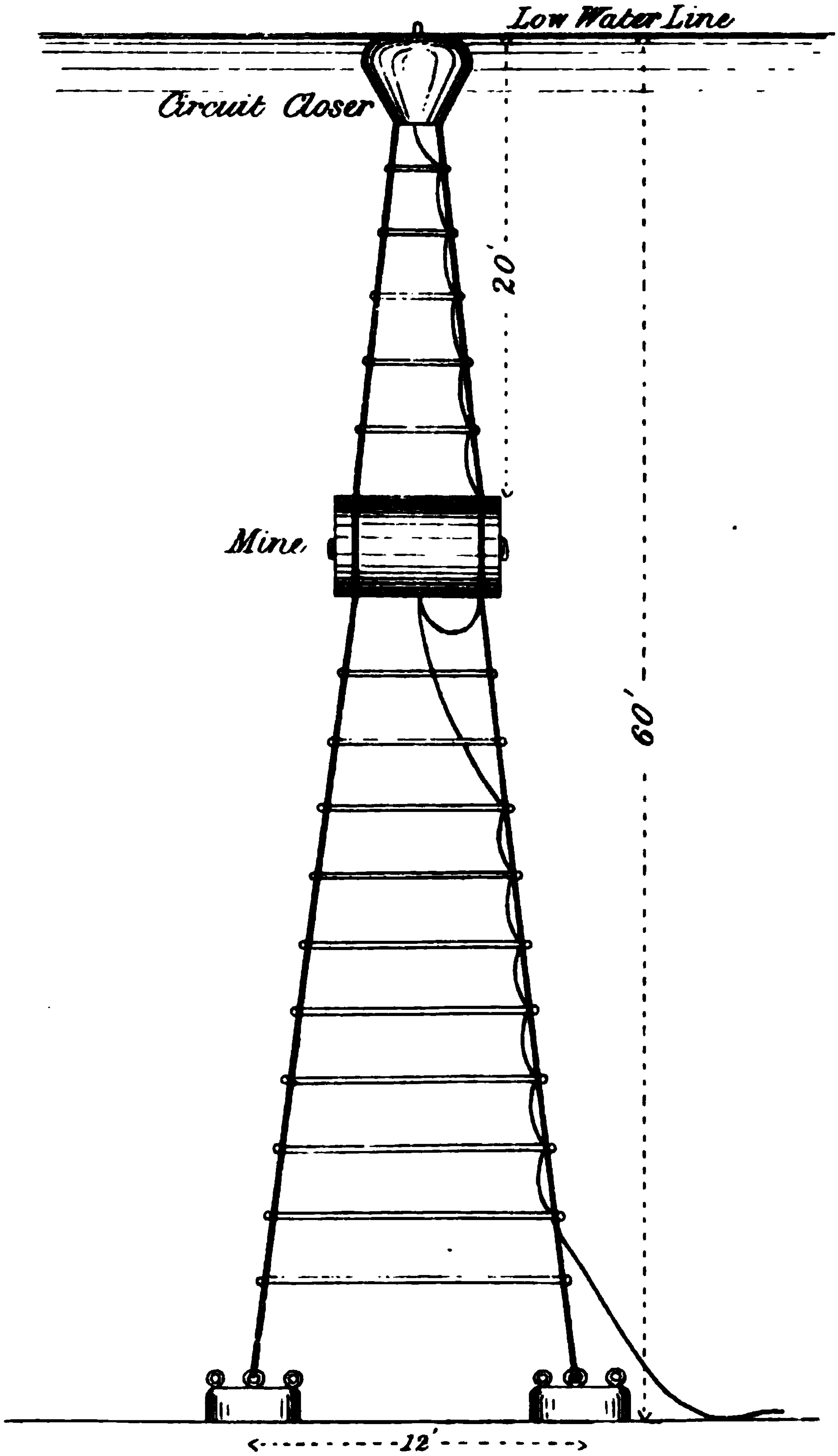
In *Plate* XI. rather more spread is shown than was used in the Hamoaze experiment. This would no doubt decrease the tendency to twist, but the broader spreaders would afford a greater space for the deposit of sea weed, &c. In deciding therefore on the particular dimensions to be employed, local circumstances, such as the quantity of sea weed or other floating matter, the strength and direction of currents, their steadiness or eddying qualities, and all similar difficulties, should be carefully considered, so as to ensure, as far as practicable, a minimum of evil in the form adopted.

Mooring fore and aft.

In a tideway where there is a current of more than five knots an hour, it may be necessary to use two anchors, placed up and down stream at a considerable distance apart, depending

PLATE XI.

LADDER MOORINGS.



Lithographed at the S. M. E. Chatham.

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SYSTEM OF MOORING SUGGESTED
BY LIEUT.T O. CHADWICK, R.E.

Fig. 1.

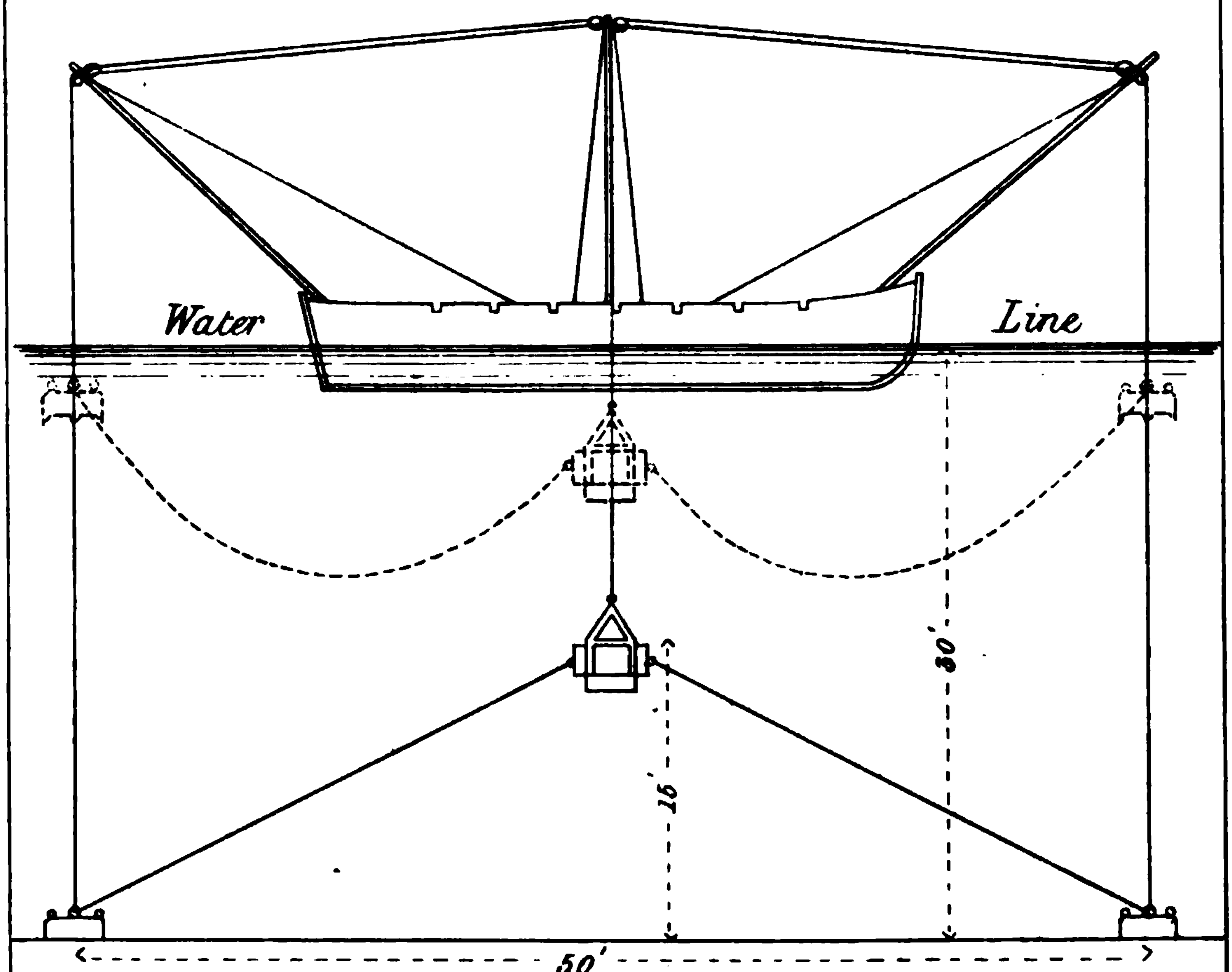
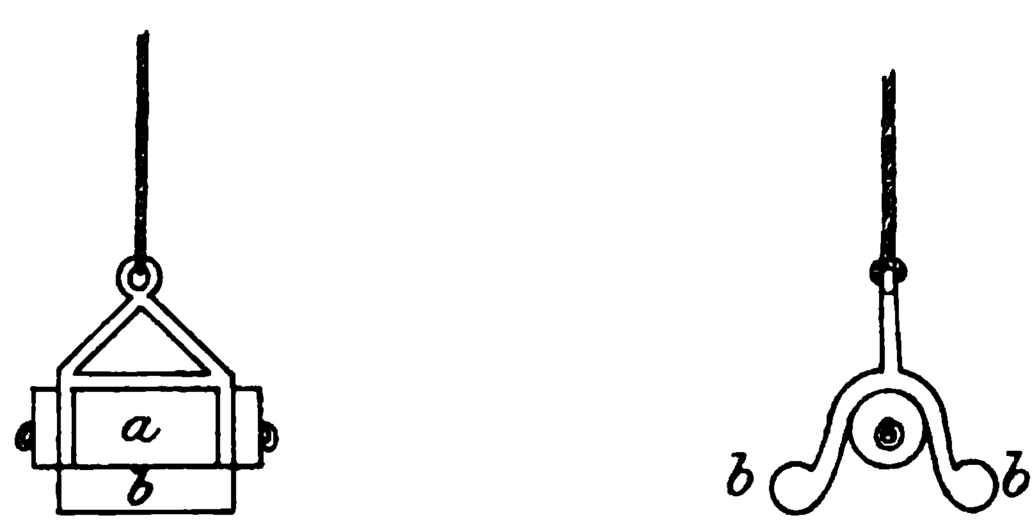


Fig. 2.



Lithographed at the S. M. E. Chatham.
B. Butler Corp.l R. E.

on the force of the current and the height from the bottom at which the mine is to float. At first considerable difficulty was experienced in placing the anchors at a correct distance apart, but by the following method small charges have been laid down successfully and have maintained their positions when so placed.

This arrangement, designed by Lieutenant Chadwick, R.E., was tried in the river Medway during the Autumn of 1867, and moorings, with a charge attached, were thereby successfully lowered into position without much difficulty.

A derrick, *Plate* XII., *Fig.* 1, was rigged in each end of a boat, the distance between the ends being that which the moorings were to have when on the bottom. To these the mooring sinkers were suspended, being attached to the ropes by nippers, which released them when on the bottom. The charge itself was made to sink by means of a heavy saddle, *Plate* XII., *Fig.* 2, placed over it, and thus its upward tendency did not draw the moorings together: *a* shows the mine, *b* the weighted saddle.

The length of the mooring cables having previously been adjusted according to the depth of water, when the moorings were placed on the bottom, the saddle was drawn up, and the charge rose into its proper position.

Small charges, of the size of 18 to 36 gallon casks, were successfully placed in this manner with a 30ft. gig, pontoon baulks being used to form the derricks.

The larger kinds of ship's boats, such as a 42ft. launch, are provided with a windlass placed across the boat, in the centre of its length. Under this are two hollow trunks fixed watertight over holes in the bottom, through these, ropes may be passed to the windlass, and in this manner a heavy object may be suspended under the bottom of the boat. A load of from two to three tons may be safely carried in this manner.

In order to place a large buoyant charge, of 1000lbs. to 2000lbs. for example, in position on Lieutenant Chadwick's principle, three of these larger boats would be required to carry it and its anchors, one for each anchor or mooring block, and one for the charge itself. They would be connected by a rope, which, if kept stretched, would ensure the anchors being placed at the proper distance apart.

In some cases pontoon rafts with triangle gyns erected on them have been used, but they are difficult to manage in a current.

Mooring Experiment off Chatham Dockyard.

Some further experiments were subsequently made in the Medway opposite Chatham Dockyard, where there was no chance of the apparatus being carried away by passing vessels, as was supposed to have been the case with those placed in the river opposite Upnor Castle. The following is the result of these experiments as reported by Lieutenant O. Chadwick, R.E.

Mooring by a single cable.

"Two large casks (36 gallon) were moored in the river with mushroom sinkers of 10cwt. each. Their total buoyancy was

about 10cwt., and each contained a weight of 5cwt., representing the charge, so that there was an upward strain on the mooring rope of 5cwt. The length of the rope was 15ft., so that the top of the barrel was about 20ft. from the bottom of the river.

"The depth of water at low water was, in one case, 20ft. and in the other 8 feet.

"A clip hook was first used, to release the mooring sinker from the tackle with which it was lowered; but this was found not to answer, from the twisting of the rope when lowering, which caused the tripping line, in connection with the arrangement, to wind round the parts of the tackle.

"The next plan used was a double rope, passing through a double block on the sheers erected on the raft and through the eye on the mushroom sinker. This arrangement also gave great trouble, from the twisting of the ropes together, and it was found impossible to clear the rope from the moorings when a single mooring cable was used."

Lieutenant Chadwick, in conclusion, recommended the following mode of lowering mines into their places to be adopted:—

"The mines, with their moorings attached, should be carried to the place where they are to be submerged, in a barge or lighter, provided with a derrick or crane, for taking them in and out.

Ship's launch fitted for mooring purposes.

"For lowering them into position a ship's launch might be used, provided with the fittings shown in *Plate* XIII., *Fig.* 1. In the centre, or perhaps rather more forward, a crab capstan *a* might be placed. Over the stern are two davits *b*, *b* with sheaves, their outer ends being about 6ft. apart. Between them is an inclined plane *c* on which the case *d*, containing the charge, is placed.

"The mushroom sinker *e* is lowered by means of two ropes, attached to two eyes in the sides, as shown in *Plate* XIII., *Fig.* 2. Each of these ropes leads through a sheave in the end of a davit, and thence to the crab capstan. By thus separating the ropes it is hoped that twisting may be avoided.

"The mine should be placed on the inclined plane, and the mushroom sinker between the davits, by means of the crane in the store lighter. This done, the boat is ready to be towed to the destined position of the mine. The anchor should then be lowered gradually down and the mine launched over the stern. To detach the ropes by which a sinker has been lowered, common marline spikes, well greased, and which are arranged to hold these ropes by being passed through a double heart knot, may be used. These marline spikes having been withdrawn, by means of lines *f*, *f* attached for the purpose, the anchor is thus released."

A 32-foot pinnace is sufficient to lower an anchor or mooring lump weighing 20cwt., but for the larger weights a larger boat would be required.

Result of ex-

A 32-foot pinnace having been fitted up as recommended by

EXPERIMENTAL MOORING ARRANGEMENTS.

Fig. 1.

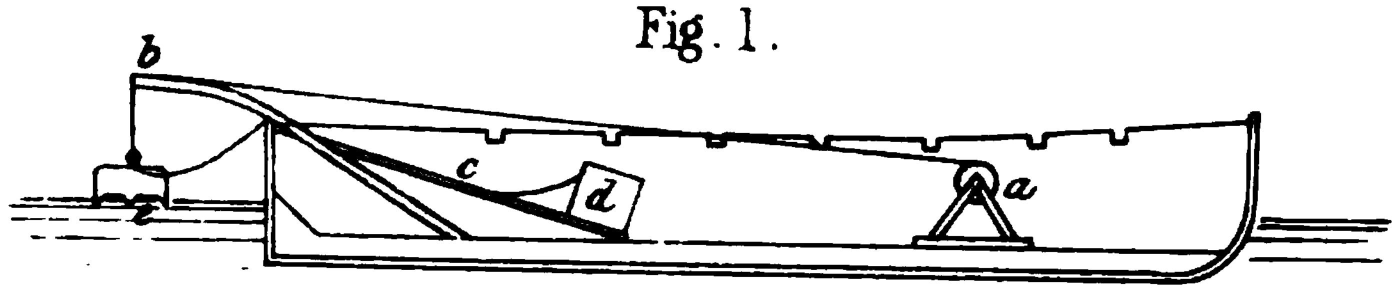


Fig. 2.

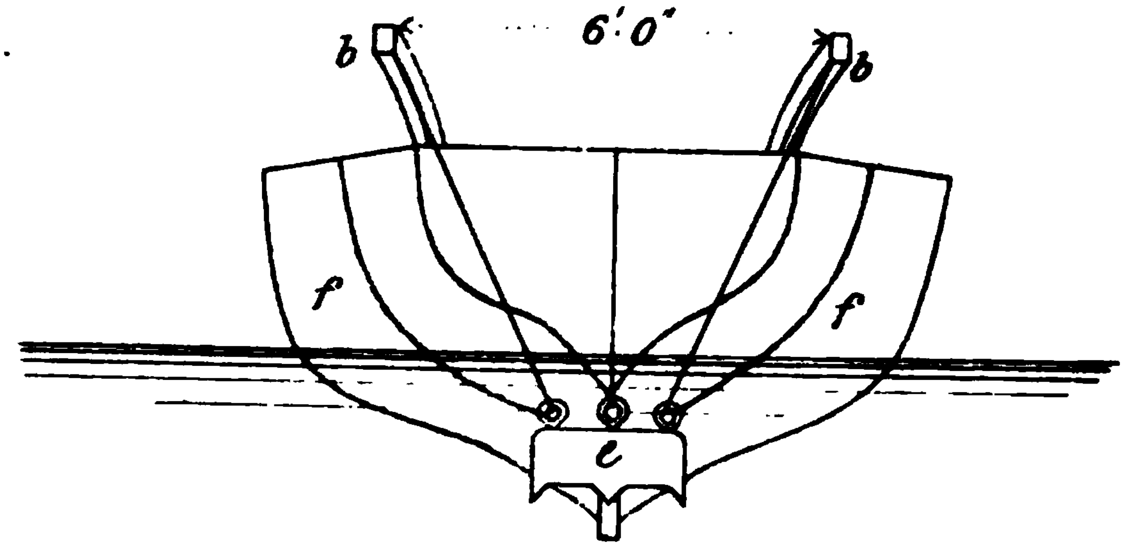


Fig. 3.

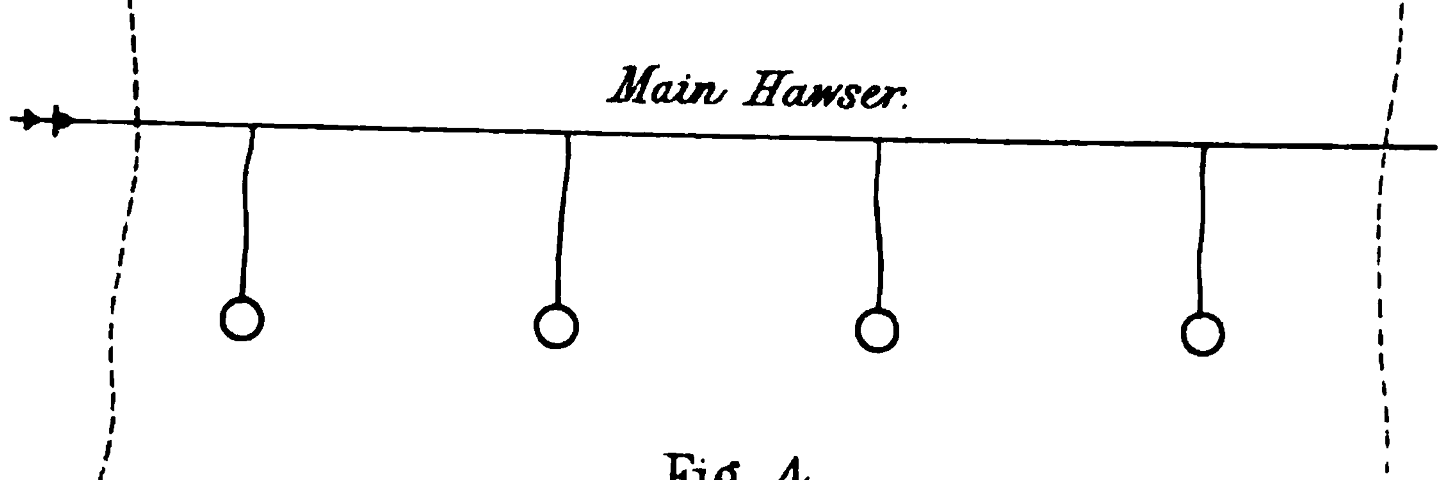
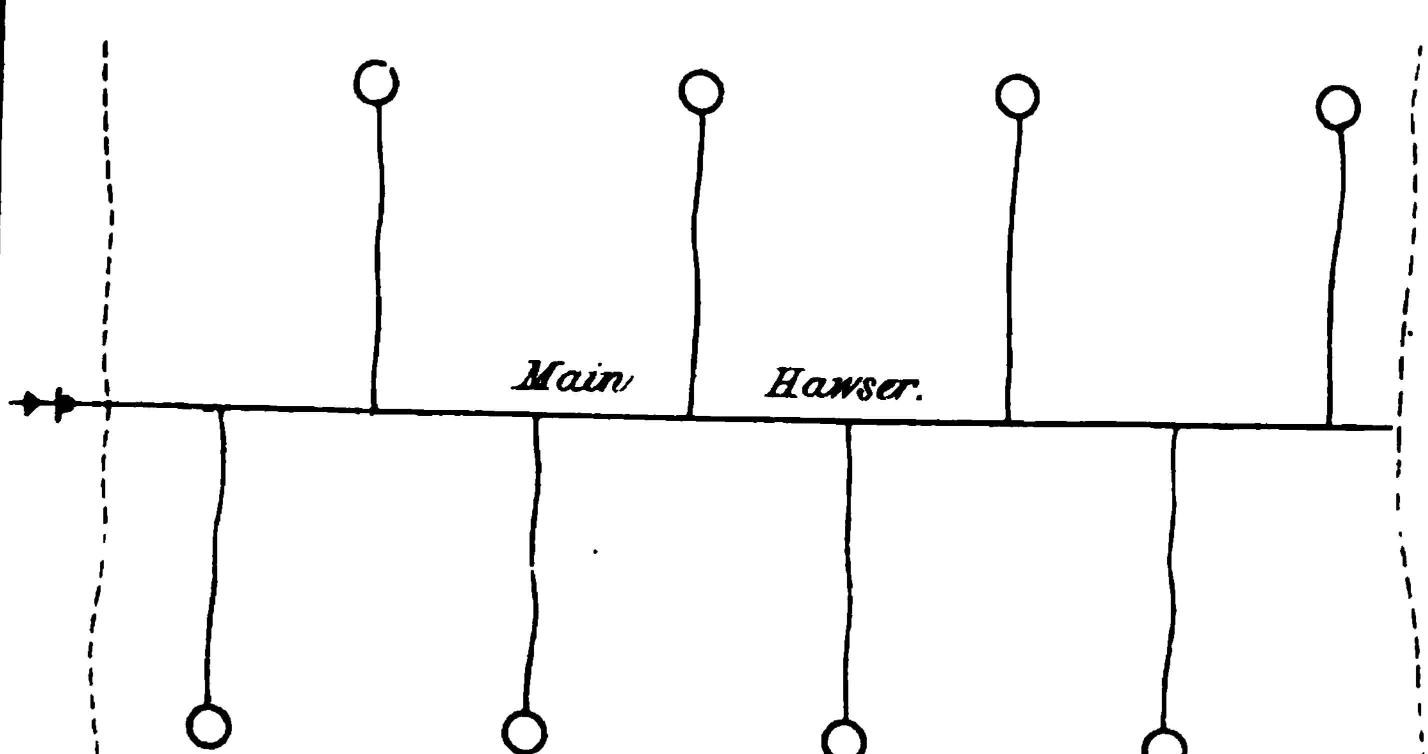


Fig. 4.



Lithographed at the S. M. E. Chatham. B. Butler Corpl. R. E.

Lieutenant Chadwick, a series of experiments was made with her during the summer of 1868. The result of these experiments showed that, though this system answered remarkably well for lowering a mushroom sinker or mooring lump into position, and there was no twisting or difficulty in detaching the ropes by which it was lowered, there was still an immense amount of care required in handling the charge and circuit closer in connection with it, in order to prevent damage to the electric cable and disarrangement of the mooring gear; and that even with a depth of only six or seven fathoms, at which the experiments were tried, and a three or four knot current, such as that of the Medway, it was so difficult to get a mine into any required definite position as to be practically impossible: under these circumstances a different system has been adopted, with more satisfactory results. In some cases, and especially in deep water and with larger charges, it may sometimes be necessary to lower the moorings first into the required position and haul the charges down to them, in order to secure that accuracy of position which is essential when a mine is to be fired by judgement; and in order to obviate, as far as possible, the great strain on the sinker, which necessarily occurs during the process of hauling down, the mine should be weighted, the weights being subsequently removed when the operation of submerging is complete.

periments in mooring, with pinnace fitted on Lieutenant Chadwick's plan.

The bottom at the point where the apparatus was placed, during Lieutenant Chadwick's experiments, was soft mud and consequently very favourable to the mushroom form of sinker. The current runs about three knots an hour at the point where the experiment was tried; the top of one barrel was just a-wash, while the mooring cable of the other allowed several feet of slack, at dead low tide. The mooring cable used was a 3-inch wire rope composed of several strands of No. 20 galvanized iron wires and manufactured by Messrs. Newall and Co. The result of this mode of mooring was most satisfactory: there was no twisting of the barrels, and consequent torsion of the mooring cable; that barrel which was moored so as to be just a-wash at low water, seemed simply to turn a little, (as indicated by a vane arranged to show above the water), but never to make even a single whole revolution, and almost immediately turned back again. The position of the barrel altered but little, whether the tide was running in or out, probably not more than two feet either way from a central point. There was, of course, more motion with the other barrel, which had a considerable amount of slack cable at low water. The wire cable was a great improvement on the ordinary hemp cable, with which the barrels, in the first experiments, were moored, and the mushroom sinkers did their work remarkably well.

Soft muddy bottom very favourable for mushroom sinker.

The conclusions arrived at from these experiments seem to be as follows:—That a single cable should be used wherever possible,

Conclusions arrived at,

from above experiments. and that a wire rope is superior to a hemp one, being less likely to twist, kink, or wear from friction. That a mushroom sinker is the best form for a soft muddy bottom. On a hard rocky bottom, the dead weight of the moorings must be depended on to keep a mine stationary, and, if a very heavy mushroom sinker is used, its edges should be furnished with toes or points, as shown in *Plate* XV., *Figs.* 1 & 2, to catch in the crevices of the rocks. Plenty of buoyancy should be given to the case to keep the charge stationary—buoyancy about equal to the weight of the charge* will suffice in a current of four knots an hour, but it might be increased with advantage in a stronger current. With a current up to four knots an hour a single iron wire cable, with a sinker which holds sufficiently, will answer every purpose, but where the current is very strong, with a rise and fall of tide, it may probably be necessary to moor with two cables, one down and one up stream, and two ordinary anchors. When two cables are used, their attachments should be placed as far apart as possible on the mine, and the anchors well spread out; the buoyancy should be sufficient to keep the cables very tight. From the experiments made at Chatham, it has been found that two cables, attached to a case close to each other, twist together immediately, and the case is by this means soon drawn down out of position. Where the best forms of sinkers or anchors are not obtainable, heavy blocks of stone, pigs of iron ballast, or any heavy weights, may be used to replace them for moorings.

The following suggestion, by Lieutenant Jekyll, R.E., is worthy of record, and would no doubt be found practicable in many cases, if not with very large certainly with charges of moderate size:—

Mooring to a heavy chain, suggested by Lieutenant Jekyll, R.E.

"Submarine mines used defensively will generally, if not always, be moored in straight lines.

"In practice the greatest difficulty is experienced in mooring any object in a particular spot, especially when two mooring chains are required, as will sometimes be the case, to prevent twisting. I suggest that, instead of sinkers, a heavy chain cable be employed to moor the mines.

"A section of the channel to be defended having been made, the line assumed by a chain could be laid down to scale. The positions of the mines and their distances apart, depth from the surface, &c., having been arrived at by calculation, could also be laid down on the section. The points where the small mooring

* Subsequent experiments in the river Medway and at the Nore, have led to a considerable modification of this conclusion. For the 500lbs. gun-cotton charges, which would always be some distance below the surface of the water, a buoyancy of two-fifths the weight of the charge has been found sufficient. For the circuit closers and 100lbs. gun-cotton electro-contact mines, which would frequently float very near the surface of the water, a much greater proportionate buoyancy than two-fifths their weight is provided.

chains of each mine meet the large chain, would appear on the drawing, and the distance of each point from either extremity having been measured off the scale, could be marked on the chain.

"Before sinking the heavy chain the small mooring chains should be rove through the links at the places marked, and the ends buoyed, sufficient length being allowed for the buoys to reach the surface.

"The conducting wires would next be laid, and the ends attached to the same buoys which support the mooring chains. In this way everything could be prepared, the cables tested, &c., before the mines were required at all; indeed, if the operation of fixing the same were practised beforehand, they need not be submerged until there was considerable probability of the mines being required for use. By keeping the mines ready loaded in suitable magazines, and having the cables frequently tested, the probability of injury would be greatly diminished.

"The great advantage of using a heavy chain, would be the absolute certainty of having all the mines in their proper places; it would also simplify the moorings by doing away with a multiplicity of anchors and anchor buoys.

"A 2½in. chain cable weighs 400lbs. per fathom. The mines would probably never be nearer than 70 or 80 feet* apart, so it is evident that the chain would be quite heavy enough to counteract any floatation which would in practice be given to them."

In a current of considerable strength it would be necessary to use two parallel chains across it, to prevent the mines swinging with the change of tide, but the same advantages would hold good.

This idea is quite compatible with the system of hauling down the mines to previously placed moorings, as it would only be necessary to supply pullies, of the form already described, shackled on to the chain cables at proper intervals and with the necessary tackle rove through them.

Placing moorings in connection with a directing hawser, suggested by Q.-M. Sergt. Mathieson, R.E.

A modification, suggested by Q.-M. Sergt. Mathieson, R.E., on Lieutenant Jekyll's plan, has been tried in the Medway, in 7 fathoms of water, and has been found to answer very well. The arrangements used were as follows:—A strong hempen cable was laid out across the river, from a mooring lighter at Hooness, the outer extremity being anchored. Previous to immersion this cable was marked at intervals, at the points where it was intended subsequently to lay down the line of mines in connection with it. In this state it might have remained at the bottom of the river for a considerable time without injury, the slack having been taken up in order to keep it in a fair and even line and prevent unnecessary movement. To place the moorings in position, the following

* This distance has been found, by experiment, to be too little for the 100lbs. electro-contact gun-cotton mines, and would be far too small for the larger charges. See approximate rule, page 44.

course was adopted:—A mushroom sinker, with gear attached, having been made fast to one of the davits of the pinnace, the directing hawser was slacked off sufficiently to admit of its being under-run, and it (the hawser) was passed over the bow of the boat at the fore rowlocks; she was warped along to the position required, as indicated by the mark previously made on the hawser. One end of a branch hawser was now bent on at this point, and the other extremity made fast to one of the eyes on the mushroom sinker, the necessary amount of slack being left to allow the sinker to be passed into its proper position. For small charges, up to 100lbs. of powder, a distance of 30ft., or a little more, from the directing hawser would probably be sufficient and, when no greater distance than this is required, it only remains to cut away the spun yarn lashings, securing the cable which retains the moorings at the extremity of the davit, and thus set free, the sinker falls into its required place. On actual service, however, much larger charges than 100lbs. would frequently be used, and it would be necessary to place the moorings at a greater distance than 30ft. from the directing cable; to do so it is only necessary to veer out the branch cable, thus letting the boat drop down to the position required, and cut away the lashings as before. The sinker having thus been got into position, any further arrangements for attaching the charge, electric cable and circuit closer may be carried on without difficulty, or the charge, circuit closer, &c. might be previously attached to the sinker and launched with it.

Favourable weather necessary while placing mines in position.

Favourable weather and a proper direction of current, especially in a tidal channel, are very essential to success when the operation of getting moorings into position is undertaken, the difficulties being much increased by a fresh breeze and rough water. It must be borne in mind that, in order to ensure a maximum of efficiency, the position of the mines must be defined within very narrow limits.

One or two lines of mines may be laid on this principle in connection with a single heavy hawser or mooring chain. The general arrangement of a single line so constituted is shown in *Plate* XIII. *Fig.* 3, and that of a double line in *Plate* XIII. *Fig.* 4.

Examination of submerged charges.

This plan affords considerable facilities for the examination of charges after they have been submerged. In order to reach any particular charge, it would only be necessary to under-run the main hawser, till the required branch was reached, by it to raise the mooring sinker, and with it the mine to be examined. In the event of the main hawser being broken, it would not be a very difficult operation to grapple it and bring it to the surface for repair. When the main hawser is not in use for any of the purposes above mentioned, all slack should be taken in to prevent unnecessary motion. This system appears to answer very well up to a depth of seven fathoms, and is very applicable to such a

EXPERIMENTAL MOORING ARRANGEMENTS.

Fig. 1.

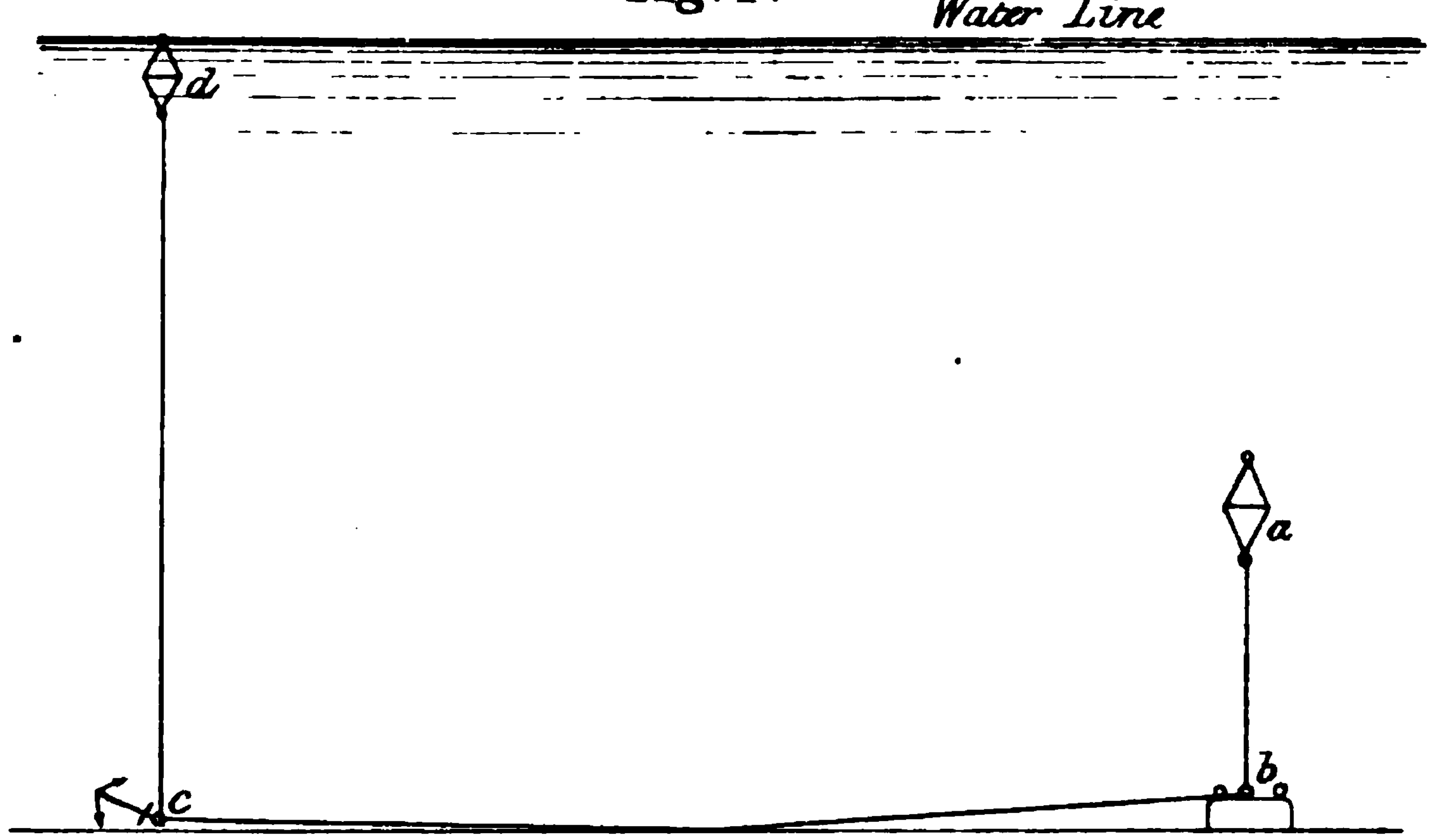


Fig. 2.

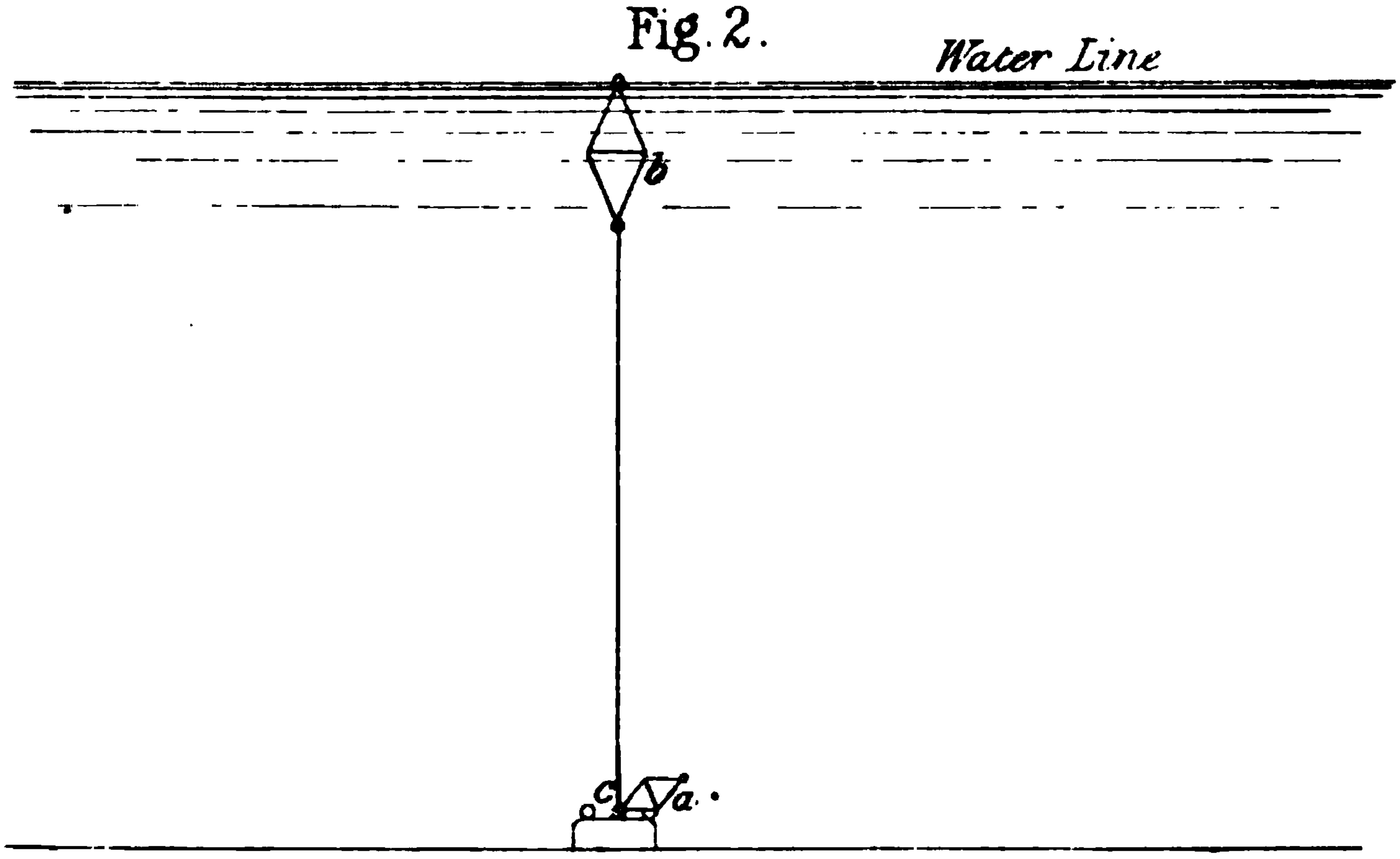
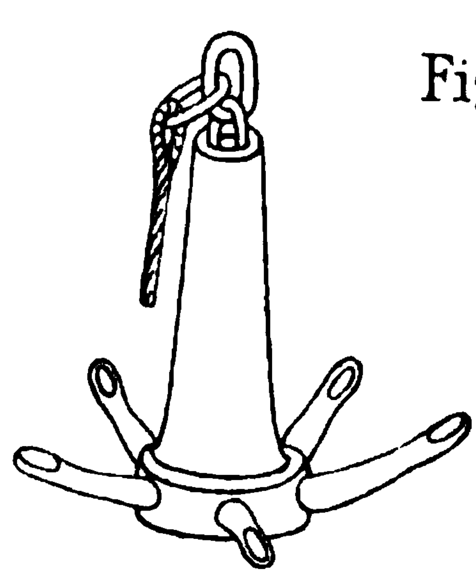


Fig. 3.



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B. Butler Capt. R. E.

position as that in which it was tested, namely, a river of moderate breadth, where several lines of mines would be required.

Subsequent experience has, however, proved that other means are better adapted for general purposes, and these experiments and proposals of Lieutenants Chadwick and Jekyll, and Q.-M. S. Mathieson, R.E., are only noticed here, as showing the means from which our present system has been worked out.

The fact, that the exact position of a mine, within a few feet, must be known to the defenders, must always be kept in view; and in order to simplify identification as much as possible, an arrangement in lines, directed on some given point, will generally be best. In a broad channel and with deep water, as for example at Spithead, the difficulties of arrangement in lines would be increased, and probably, in such a case, it would be necessary to anchor a couple of large vessels fore and aft and, after hauling them into exact line, to connect them by a hawser, by which latter the boats, engaged in lowering the moorings, or mines, would be guided.

It might in some cases, be not only desirable but necessary to place the moorings in position at leisure previously, and thus the most difficult and tedious part of the operation being done, a channel could, on a threatening of hostilities, be very rapidly put in a state of defence.

Power of working the running gear of any hauling down arrangement must be retained.

When an anchor has been placed in position, it is necessary to retain the power of working the running gear, in connection with the hauling down arrangement, in a practical form, and for this purpose the method shown in *Plate* XIV., *Fig.* 1, is suggested. In this arrangement a buoy *a* is placed in connection with one end of the cable, rove through the pulley *b* shackled on to the eye of the mushroom sinker, while at the other end an ordinary anchor *c* is attached. This latter is cast at such a distance from *a* that there is no chance of entanglement between the cable attached to the latter and that in connection with the anchor buoy *d*. By this arrangement it is manifest that, by weighing the anchor *c*, both ends of the line, rove through the pulley or loop *b*, may be obtained at any moment with facility, and there is no chance of the two parts of the mooring cable becoming twisted round each other, however long they may have remained submerged. It is essential to efficiency that there should be no such winding round each other of the two parts of the cable, as even a single turn would destroy the action of the running gear through the pulley. If the buoy *d* cannot be conveniently used, the anchor *c* may be deposited in position without it and, should it be necessary to weigh it, the line *b c* could be easily grappled and brought to the surface, sufficient slack being allowed for this purpose. An ordinary weight of any sort, sufficiently heavy to counteract the upward pull of the buoy *d*, might be used instead of the anchor *c*. The buoy *a* should be kept some distance below the surface, as well

to prevent injury to it by vessels striking it as to keep its position, which would indicate that of a future submarine mine, secret.

Arrangement of running gear, suggested by Quarter-Master Sergeant Mathieson, R.E.

A modification of this plan, shown in *Plate* XIV. *Fig.* 2, has been suggested by Quarter-Master Sergeant J. Mathieson, R.E. It consists in simply arranging two buoys, one at each end of the running gear, passing through the pulley or loop *c*, in such a way that the buoyancy of one of them as *b* shall considerably exceed that of the other *a*, and the latter, having been hauled down close to the moorings, would be held there till required to be moved. In such an arrangement, care must be taken to make the buoy *a* sufficiently strong, to resist the continuous pressure of the water at the depth at which it is required to remain. It possesses the advantage over the system first described of greater simplicity, but is more easily disarranged, for if the buoy *a* rose slightly, from any depression of the buoy *b*, there might be a certain amount of slack in the cable, and a consequent capability of entanglement by twisting round that part of it attached to *b*, which would at once destroy the efficiency of the combination. It has, however, been tried practically in the Medway, in five or six fathoms of water, with considerable success,

Whichever of these plans is adopted, the utmost care is requisite to keep the cables and buoy lines clear, during the process of lowering the moorings, as well as in subsequent manipulations, as any entanglement would be fatal to success, and more care is necessary with the second method than with the first. After having been laid down, they should be examined at intervals to see that the running gear is in working order.

A mine on the bottom must be so heavy as to remain stationary.

Where a charge is to be laid on the bottom, it should be of sufficient weight to ensure its remaining stationary. Lieutenant Wallace, in his account of the demolition of wrecks in the Hoogly, gives his experience, as follows: "Sometimes, in a strong tideway, a charge of 500lbs. of powder required a weight of about 400lbs. to sink it; whereas in slack water less than half that amount was sufficient." These weights, of course, refer to charges arranged in barrels, as used by him, and the weight of any particular form of case must always be taken into account.

Mode of placing a charge in position.

The next point to be considered is the best method of lowering a heavy charge into its position at the required depth below the surface, and, when lowered, of attaching it to the sinker. Two modes have been suggested by which this may be effected: either by first measuring the depth of the water by sounding, then attaching the sinker, with the necessary amount of cable, and lowering both together, or by lowering the sinker first, and drawing the charge down to it, and, when it has reached the required depth, there fastening it securely.

The first plan shall be explained hereafter in treating of the several methods of submerging mines. Our experiments have proved that it is quite practicable, in this manner, to place a

mine in a position, the limits of which are defined; it requires care, however, in execution, and trained men as well as favourable circumstances of weather and currents, to perform it well in an open sea, even with small charges and moderate depths of water. By the second method a mine might be placed very quickly and accurately in position, if the moorings were in the first instance accurately laid down. In practice, however, we have found the first method quite practicable with a 500lb. charge, up to a depth of 10 or 12 fathoms, in the open sea.

Barge used by Austrians for mooring submarine mines.

The Austrians employed a large boat or barge, on which a derrick was erected, by which the sinker or mooring arrangement, was first lowered into its place. To this sinker was attached a certain amount of wire cable, to the upper extremity of which was fixed a pulley, *Plate* VIII., *Fig.* 2, already described. Before the sinker was lowered into the water, an iron chain, attached to the case, was passed through the pulley, and by it the charge was drawn down to any required depth and there held by the self-acting arrangement, previously alluded to, see *Plate* IX., *Fig.* 1, p. 61.

When the heavily weighted wooden platform, also used occasionally by the Austrians for mooring purposes, was employed, the charge was held down to the required depth by three mooring cables, one attached to each angle of the platform, and the only difference was that three pulleys and keying arrangements were required instead of one, as used with the sinker. The Austrians however, carried on their operations where there was no tideway, but it is probable that a charge, moored by three cables in this way, might twist and be drawn down, if acted on by a current, unless the three points, to which the cables were attached, were placed very far apart.

Pontoon raft used for mooring purposes.

In our experiments at Chatham, the apparatus at first used for placing the charges in position, was composed of any materials that could be obtained on the spot; and we have since gone into the question of the special means and arrangements best suited for the purpose. Some of the charges, moored in the earlier stages by a single mushroom sinker, were lowered from a pontoon raft, by means of a derrick erected thereon. A raft of this nature forms a tolerably good platform, from which to carry on such an operation in smooth water. It possesses one serious disadvantage however, namely, that there being no gunwale, small stores were frequently pushed overboard and lost. If, therefore, a pontoon raft is ever used, as a makeshift, for such a purpose, it would be desirable to add a temporary gunwale to it.

Experience derived from experiments at Chatham.

Our experience in mooring submarine mines may be summed up as follows:—

1st. When it is necessary to place the moorings in position at leisure, be very careful to get them into the exact sites, previously decided on, for the mines.

2nd. Arrange all running gear in the simplest form, and try it at intervals to see that it keeps in good order.

3rd. When a channel, in which the moorings have been previously placed, is to be put in a state of defence, it is only necessary to bring the charges to the required point and haul them down into position.

4th. With a current up to four knots an hour, a mine may be efficiently moored with a single wire cable, provided plenty of buoyancy is given.

5th. With a current of four knots an hour or more, where the charges must be held in a defined position, it may be necessary to moor them fore and aft. For this purpose a double line of moorings is required, and in hauling down it would be necessary to take care that the top is horizontal when the mine is in position.

6th. Under ordinary circumstances, that is to say, with a depth up to 10 or 12 fathoms, it has not been found necessary to place the moorings first in position and haul the mines down to them. It is only necessary, after ascertaining the depth of the water, to connect the mine, sinker and circuit closer with the required lengths of mooring cables, and to drop the whole into position from a boat specially fitted for the purpose. This would be the ordinary mode of proceeding in the majority of instances, and the circumstances, under which it would be necessary to haul a mine down into its place, would probably be exceptional.

Approved mushroom sinkers.

The most approved forms of sinkers, for use with submarine mines, are shown in *Plate* XV. *Figs.* 1 & 2 show a plan and side elevation of two sizes of mushroom sinkers, of the form approved for mooring buoyant mines; these are formed of cast iron and weigh respectively 7 cwt. and 5 cwt., to suit the sizes of charges recommended for service, and the other conditions to be fulfilled. There are three rings on the top for connecting the mooring cable, buoy line, &c., and for any temporary attachments that may be required during the process of lowering the mine into position. The bottom of the sinker is slightly hollow, and is provided with three toes to prevent lateral motion, as far as possible, by sticking into the holding ground. The sides are made flat and perpendicular to the top, to enable the sinkers to be rolled along with facility when they are required to be moved for short distances. A flat form has been intentionally adopted, so as to keep the point of attachment of the mooring gear low, and thus prevent any tendency to tilt over on the application of a side strain.

Sinker for ground mines.

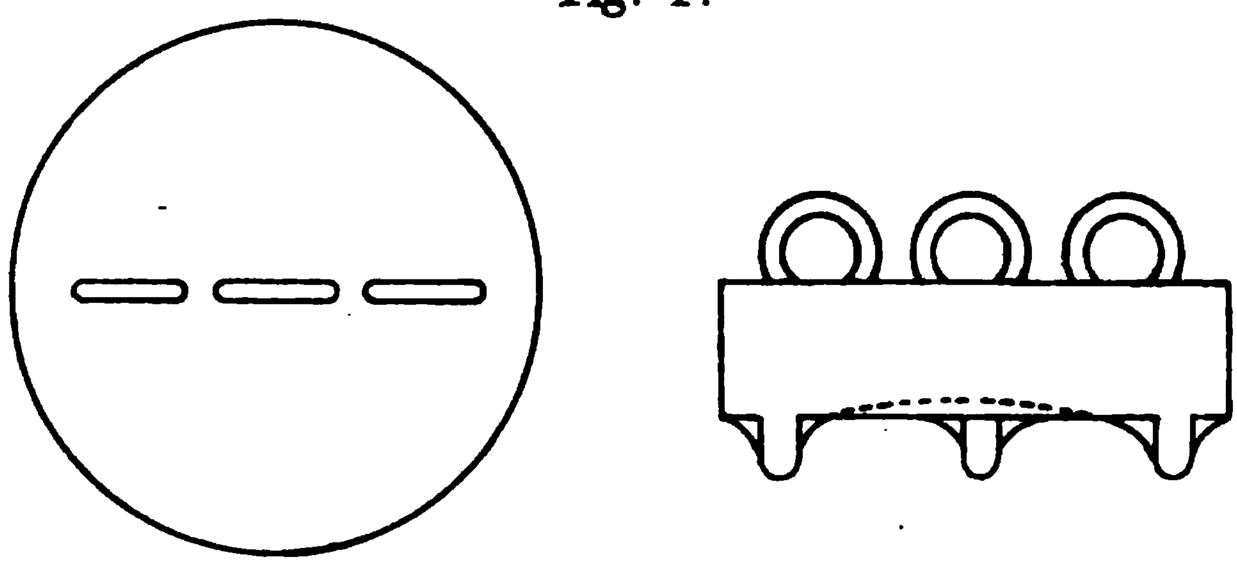
Fig. 3, *Plate* XV., shows an end and side elevation of a 3 cwt. oblong sinker, specially designed for attachment to a 500lb. ground mine. The top of this is hollowed out to fit the circumference of the case, and rings are provided for the connections of the chains by which the sinker is lashed on to the mine.

Boats specially fitted

Boats, provided with certain special fittings, such as a small davit, crab, &c., are required for placing the mines in position;

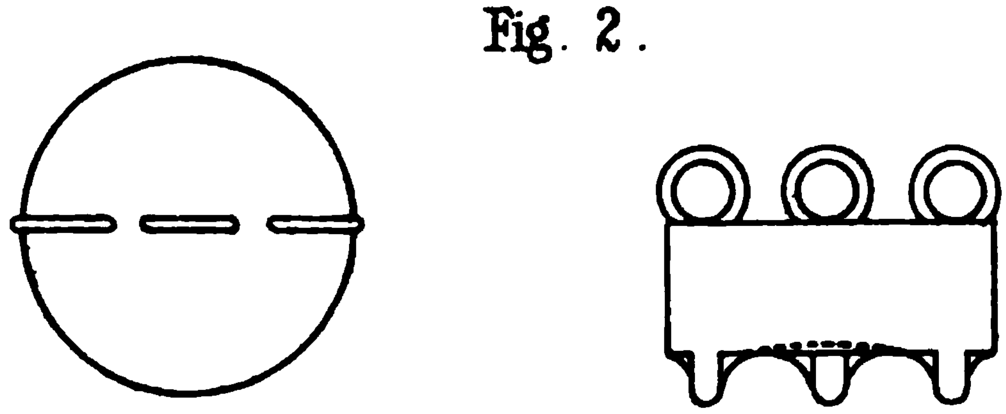
SINKERS FOR SUBMARINE MINES.

Fig. 1.



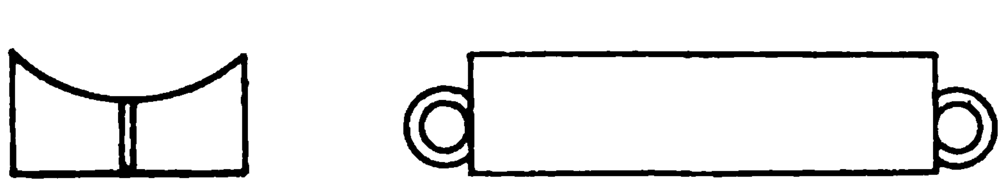
MUSHROOM SINKER, 7 CWT.

Fig. 2.



MUSHROOM SINKER, 5 CWT.

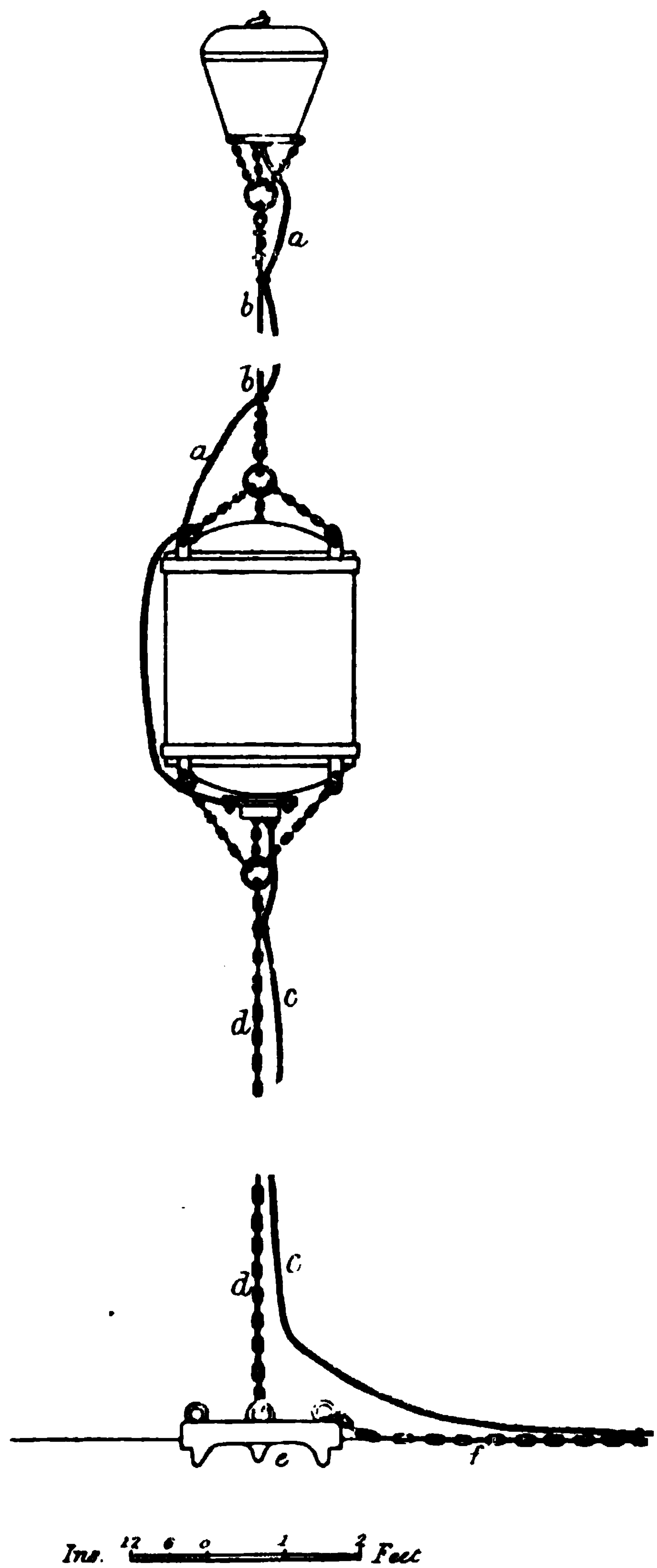
Fig. 3.



OBLONG SINKER, 3 CWT.

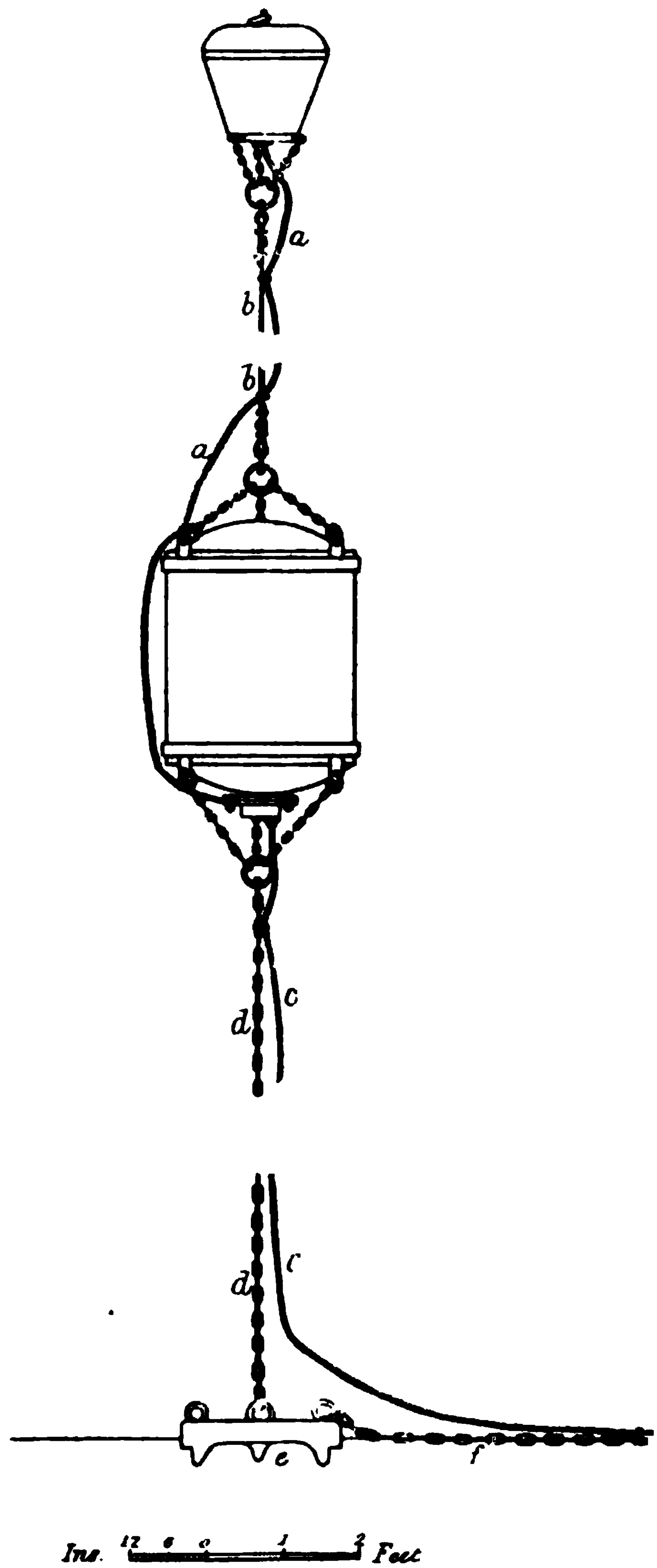
Lithographed at the S.M.E. Chatham. B. Butler, Corp.l R.E.

MODE OF MOORING BUOYANT SUBMARINE MINE OF 500 LBS. GUN-COTTON, WITH CIRCUIT CLOSER.



Lithographed at the S.M.E. Chatham. B. Butler, Corpl. R.E.

MODE OF MOORING BUOYANT SUBMARINE MINE OF 500 LBS. GUN-COTTON, WITH CIRCUIT CLOSER.



Lithographed at the S. M. E. Chatham.

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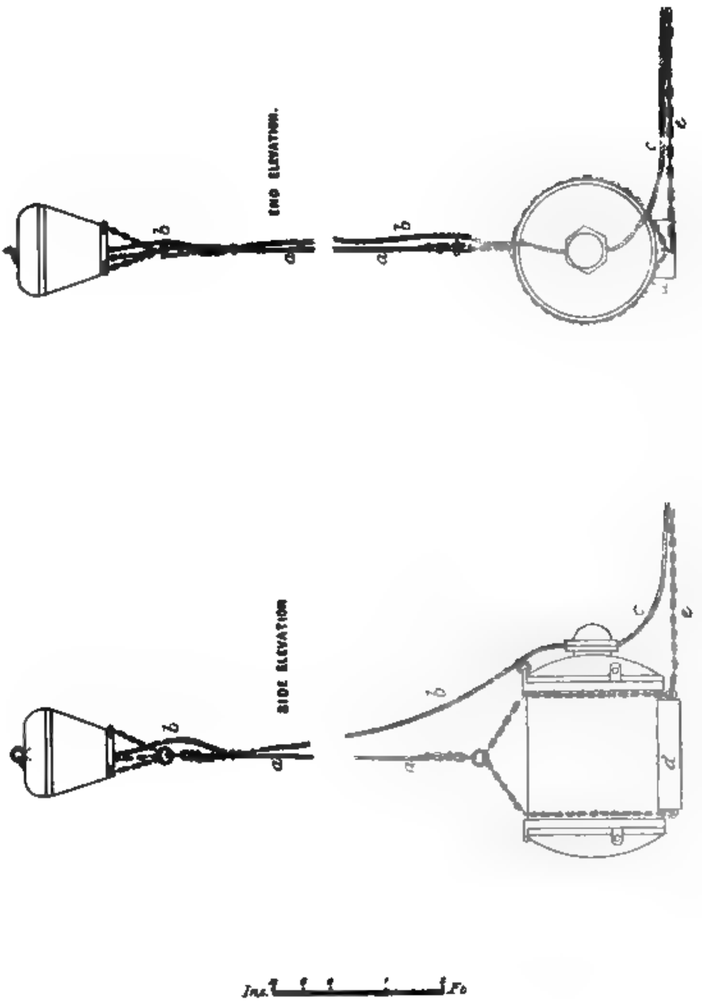
PLATE XVII.

MODE OF MOORING 500 LBS. GROUND SUBMARINE MINE,
WITH CIRCUIT CLOSER.



Lithographed at the S. M. E. Chatham

B. Butler, Corpl. R. E.

these shall be described hereafter. A small steamer, of the tug class, and a lighter, or small hulk, capable of carrying 14 or 21 mines with their mooring gear, electric cables, &c., would be necessary where extensive operations are required to be carried on.

for mooring submarine mines.

Steamer and lighter for mooring service.

Plate XVI. shows the mode of mooring a 500lbs. buoyant, gun-cotton charge, complete with its electric cable, mushroom sinker and mooring gear. *a*, *a* is the electric cable, protected with wire strand armouring, between the charge and the circuit closer; a special protection has been found necessary for the electric cable at this point, for reasons which shall be hereafter discussed. *b*, *b* is a 2-inch Bessemer steel wire rope, connecting the circuit closer to the charge. The electric cable *a*, *a* is stopped at intervals to the Bessemer steel wire rope *b*, *b*, leaving plenty of slack. *c*, *c* is the ordinary armoured electric cable, connecting the charge to the junction box and thence to the testing room on shore. *d*, *d* a $\frac{3}{8}$-inch mooring chain, connecting the charge to the 7cwt. mushroom sinker *e*. The electric cable *c*, *c* is stopped at intervals to the mooring chain *d*, *d*, with plenty of slack. *f* is a $\frac{7}{16}$-inch tripping chain, connecting an outer ring of the mushroom sinker to the electric cable *c*, and stopped to the latter at intervals, so that should it become necessary to raise the mine, it may be done by under-running the electric cable *c*, by which the tripping chain *f* would be brought to the surface, and the mushroom sinker would be raised, while all strain upon the electric cable itself, and the connections between the charge and circuit closer would thus be avoided.

Mooring attachments for 500lbs. buoyant mines.

Plate XVII. shows a side and end elevation of the arrangements approved for mooring a 500lbs. ground, gun-cotton charge. *a*, *a* is a 2-inch Bessemer steel wire rope connecting the charge and circuit closer. *b*, *b* the electric cable, between the charge and circuit closer, specially protected with strand wire armouring. The electric cable *b*, *b* is stopped at intervals to the Bessemer steel wire rope, with plenty of slack. *c*, *c* is the ordinary armoured electric cable, connecting the charge to the junction box and thence to the testing room. *d*, *d* a 3cwt. oblong sinker of the form shown in *Fig.* 3, *Plate* XV.; this is attached by chains to the case as shown in the drawing. These chains pass completely round the case and are shackled to the rings on the oblong sinker. *e*, *e* is a $\frac{3}{8}$-inch tripping chain, connecting the ballast to the electric cable *c*, *c* and stopped to the latter at intervals. This tripping chain is intended for weighing the mine, when required, and should be long enough for that purpose.

Mooring attachments for a 500lbs. ground charge.

Plate XVIII. shows the mode of mooring the 100lb. gun-cotton mine. In this plate the mode of mooring shown is that which would be employed, when it (the mine) is used as an electro-contact charge on the branch system, as suggested by Qr.-Mr. Sergt. Mathieson, R.E. Under such circumstances the branch which connects the charge with the main electric cable, is at-

Mooring attachments for 100lb. gun-cotton electro-contact mine.

tached, through a special apparatus, to one pole of a platinum wire fuze, while the other pole is connected to the circuit closer and, through this, when struck, would be put direct to earth. The branch electric cable is seized to the 2-inch Bessemer steel wire rope *c*, by spun yarn, at the point *a*, close below the ring connecting the mooring cable to the attachment chains of the charge. *b*, *b* are galvanized iron thimbles, round which the Bessemer steel wire rope is secured, and through which the connecting shackles are passed. *d* is the main electric cable, connecting the group of mines to the shore. A 5 cwt. mushroom sinker is employed for mooring mines of this size; *e* is the ground line on which the sinker rests. *f* is the T connecting box, within which the junction between the branch and the main cable is made. In this case the branch cable is seized at one point only to the steel wire mooring rope, and that close to the connection of the latter with the attachment chains; these charges would always be used near the surface, and if it were required to raise one of them for any purpose, it would only be necessary to approach it at low water, when it would be a-wash or nearly so, and by passing a boat-hook into the attachment ring, raise the mushroom sinker direct, by means of the Bessemer steel wire rope.

The branch arrangement of mines shall be explained in detail hereafter.

The 100lb. gun-cotton mine may be used, when the conditions of the case are favourable to such small charges, either as a single mine on the electro-self-acting system or to be fired by observation. In the latter case, the fuze and earth connections would be arranged in the same way as those for the larger mines, described in pages 54 and 55, and shown in *Plates* V. and VI. As, however, this is essentially a contact mine, it would seldom be desirable to arrange it to be fired by observation. If moored in this way a tripping line, from one of the outer rings of the mushroom sinker, would be required, and the electric cable would be stopped at intervals, with plenty of slack, to the Bessemer steel wire mooring rope. In the 100lb. mine the circuit closer is always within the case itself, which also contains the charge.

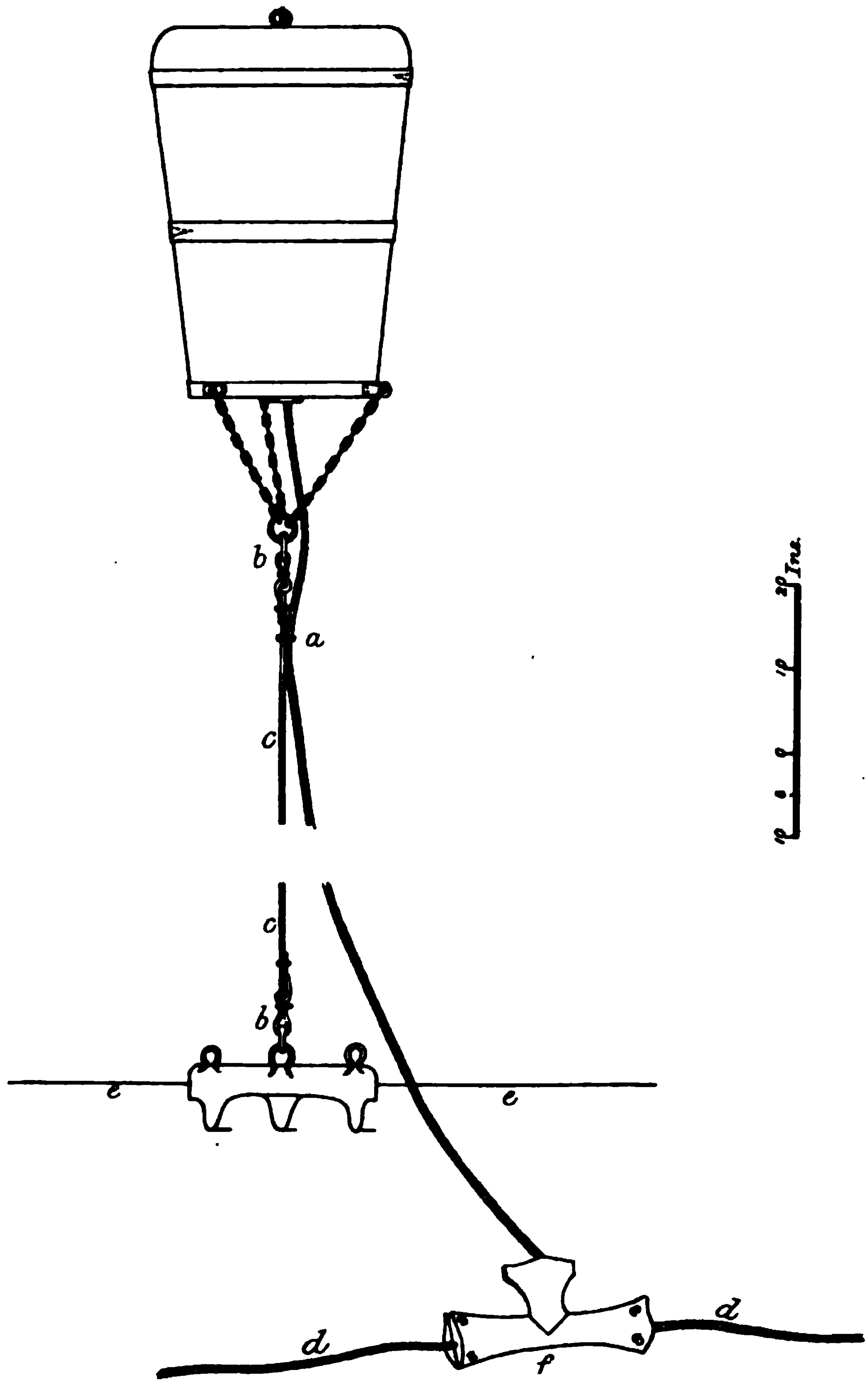
Mode of mooring with a considerable rise and fall of tide.

There is one problem, with reference to submarine mines, which has still to be solved, namely, that of mooring in a spot where there is a considerable rise and fall of tide, so as to show no indication, or at least a minimum of indication, on the surface as the depth of water decreases. Many suggestions have been made with a view to the solution of this question, but none can be said to be completely successful.

Mode of mooring suggested by Quarter-

Quarter-Master Sergeant J. Mathieson, R.E., has suggested the use of a small buoy, just sufficient to give that amount of floatation necessary to keep a circuit closer always suspended at a given distance below it, the circuit closer itself being slightly heavier

MODE OF MOORING 100 LB. ELECTRO-CONTACT GUN-COTTON MINE.



Lithographed at the S. M. E. Chatham.

B. Butler, Corp.l R. E.

than its bulk of water. The arrangements of this plan were found to be too delicate to be practically useful; the slightest leak in the small buoy at once disarranged the efficiency of the combination; any lodgment of seaweed, or other floating matter, was also equally fatal, as it increased the weight and consequently disarranged the very delicate balance necessary to successful working; and the small buoyancy of the whole combination, rendered it liable to be acted on by a comparatively small current and thrown out of position, which, for reasons already given, would be a serious objection. *Master Sergeant J. Mathieson R.E.*

Lieutenant W. E. Peck, R.E., has suggested the use of a compressible buoy, arranged to act, through a pulley, so that as the water fell and the pressure was consequently reduced, it would expand, and, by the increased flotation thus acquired, draw down a charge, in connection with it, through a pulley. An india-rubber buoy might no doubt be made to fulfil the necessary conditions as to compressibility, but there would be great difficulty in getting any combination so nicely balanced, as that suggested must necessarily be, to work automatically through a pulley, which had been submerged even for a comparatively short time; the friction occasioned by oxide has been found, under such circumstances, to be very great. *Mode of mooring suggested by Lieut. W. E. Peck, R.E.*

Lieutenant R. F. Moore, R.E., has suggested hauling a line of mines or circuit closers down mechanically, by means of a cable connected therewith, made fast at one extremity to the outer mine or circuit closer in the system, attached to the other mines or circuit closers at their proper intervals, and passing through a fixed pulley to a windlass at the other. The pulley, through which the cable passes to the windlass, must be below the lowest level to which it is necessary to haul down the mines, and consequently below the surface of the water. In order to raise or lower the mines thus arranged it would only be necessary to slack out or haul in the cable, by means of a windlass, as required, and it is easily seen that a comparatively small amount of cable taken in or let out would effect the necessary difference of level in the mines. In such a combination the mines should have plenty of buoyancy. *Mode of mooring suggested by Lieut. R. F. Moore, R.E.*

In this system it is to be feared that the friction, inseparable from the use of pulleys submerged for any length of time, would act prejudicially. This combination has still to be tested; it seems, however, worth trying, and if successful might probably be used in certain positions with advantage, especially if the number of mines attached to each cable was not very great.

In the absence of any reliable system of mooring, to fulfil the necessary requirements with a considerable rise and fall of the tide, and for the present we cannot lay down any definite rules on this point, it would be necessary to arrange the mines to float at such permanent levels, as to be sufficiently near the surface at high water to act effectually, and yet not so near as to be very *Stationary arrangement of mooring for a channel with considerable*

rise and fall of tide. visible at low water. By the use of large charges with a proportionately large radius of explosive effect, this might probably be done except in extreme cases; and where it would be impossible

When necessarily visible circuit closers, &c., to be disguised. to keep them absolutely out of sight, the mines and circuit closers might be covered with seaweed, or disguised in any suitable way, in order to conceal to the utmost their real nature.

In all cases, and in this especially, dummies should be freely used to perplex an enemy and conceal the position of the real mines. These dummies should bear a close resemblance to the real cases or circuit closers, should only be sufficiently con-

Use of dummies. spicuous to attract attention, without revealing their real character, and might be placed in any convenient position, or even occasionally shifted at night, so as to increase the delusion and perplexity.

Extemporised moorings. A mushroom sinker is in most cases, and especially on a soft muddy bottom, the form which seems best adapted for mooring submarine mines. Such articles may not, however, always be at hand, and it may become necessary to use some extemporised arrangement. That shown in *Plate* XIV., *Fig* 3 and consisting of a strong heavy wooden shaft with a number of wooden arms or flukes, shod with iron, was, after experiment, considered a very good form by the authorities of the United States of America. This might easily be made wherever hard-wood timber is available.

Again the wooden weighted platform of the Austrians is one that might be easily constructed in many cases. It seems particularly applicable where a charge is to be moored over a rocky, and yet level, bottom or bad holding ground, where it must be kept in position by the dead weight of the arrangement. The wooden platform affords a broad space on which any number of heavy weights can be conveniently placed and the materials of which it is formed, viz., wood and iron, are procurable everywhere. The system of mooring by three cables seems objectionable as, with a current, they would be very likely to become twisted together, but there is no reason why a single cable from the centre should not be adopted, if proper precautions to strengthen the connection of the central point, to which the cable would be attached, with the outside, by means of iron stays or in some other manner, were used.

Ordinary anchors. It is unnecessary to describe how ordinary anchors may be used for mooring submarine mines.

Large stones, pigs of ballast, &c. Large stones, pigs of ballast, or any heavy weights may be used where the more appropriate forms of apparatus cannot be obtained. These must necessarily be sufficiently heavy to hold a mine in position by their simple dead weight. The Germans used large blocks of stone very extensively, for mooring their submarine mines during the war of 1870-71, and found them very efficient.

Weight of moorings. A very important point for consideration is the weight of the anchor or mooring apparatus, necessary to hold any given size of

charge in position. This will depend on its buoyancy and the strength of the current in which it is to be moored, and also on the nature of the bottom or holding ground.

The Austrians recommend very heavy moorings, as much as seven times the weight of the charge of powder, in certain cases. This is necessary, because they always use buoyant charges hauled down to their proper position, after their moorings have been placed. The large excess of weight, acts against the strain in hauling through the block, which is, of course, equal to that of the buoyancy on each portion of the rope, or double on the whole. Without a considerable excess of weight, we have found that, during the process of hauling down, the moorings are very liable to be drawn out of position.

Calculation of weight of moorings.

As, however, the tendency to move depends on the amount of buoyancy, the pressure exerted by the current and the tenacity or otherwise of the holding ground, the weight of sinker or mooring apparatus, necessary to overcome that tendency to move, may be easily calculated as follows. Let B be the buoyancy, or excess of floatation over weight of a charge of a given submarine mine; let P be the pressure exerted by any given current on the same mine, when moored to the bottom and floating freely therein, it is evident that the resultant of these two forces, or $\sqrt{B^2 + P^2}$, gives the force tending to move the mine out of its position. Now, suppose a case where the water is absolutely still, P becomes nothing, and the force tending to move the mine, would be simply equal to B, the buoyancy, and that force would be exerted in a vertical direction. To balance this we should require an effective weight exactly equal thereto, and taking into consideration the necessity of providing an excess, in order to keep the mine stationary, it would be necessary at least to double such weight in practice. In calculating the weight to be opposed to the floatation, in order to keep a given mine from drifting out of position in consequence of the action of a current, the effective value of the anchor or moorings must be taken, or its weight in air minus the weight of water displaced by it. The loss of weight by immersion would, of course, depend on the bulk of the mooring apparatus to which the mine is attached, and, when that bulk is considerable, it becomes a most important consideration in the calculation; when a simple iron mushroom sinker is used it is probable that its weight, if double the buoyancy, would be amply sufficient in perfectly still water. Again, let W be the weight of moorings required; if the foregoing conclusions are correct we should then have

$$W = 2\sqrt{B^2 + P^2}$$

In still water, where $P = 0$, W would be equal to 2 B or double the buoyancy, as already assumed to be sufficient.

Where it is intended to haul a mine down to moorings previously

Amount of buoyancy.

placed, considerably more than double the buoyancy would be necessary, for the reasons already given.

A very important element in the above is the amount of buoyancy necessary to be given to a buoyant mine, and here again we must start from some kind of assumed basis, and from the experience we have had in mooring operations in the Medway and at the Nore, it would seem that in still water, or in a current up to 4 knots an hour, the buoyancy should not be less than $\frac{2}{5}$ of the weight of the charge: this is the net buoyancy, required for a 500lb. mine complete with the charge, but not including the attachment chains and mooring and electric cables. For example, a 500lb. charge should have a net buoyancy of $\frac{2}{5} \times 500 = 200$lbs. which would be reduced by the weight of the attachment chains and mooring and electric cables, to a working buoyancy of about 150lbs. In a case where there is an exceptionally strong current, in which mines must be anchored by comparatively long mooring cables, considerably greater buoyancy might be necessary, and for such conditions exceptional measures must be taken to provide this additional floating power. It is probable that, in most cases, the force of the current decreases in proportion to the depth below the surface, and with this idea the buoyancy provided for circuit closers, and for the 100lb. buoyant electro-contact mines, which are required to float near the surface, is much greater in proportion to their weight, than that of the larger charges, which would be more deeply immersed. The buoyancy here given for a 500lb. charge, has been found to be sufficient for all practical purposes, in the case of the mines which have been moored in position in the Medway and at the Nore for experimental purposes, some of which have remained submerged for several months.

In any case when a buoyant mine is to be retained within certain limits, when moored with a given length of cable and acted on by a known current, it is a very easy matter to calculate the buoyancy necessary to produce the required result. An excess of buoyancy over the minimum recommended for service is always desirable, to obviate the ill effects of slight leakage or any other disturbing cause, which might tend to reduce efficiency, especially where imperfect or make-shift arrangements are employed.

Muddy bottom favourable for mooring operations.

The deductions to be derived from the above statement are applicable only to cases in which the bottom is hard, and the mine must be held in position by the simple dead weight of the anchor or mooring apparatus to which it is attached. When the bottom is soft this weight may be considerably reduced, and in an extremely soft muddy bottom like the Medway it is probable that three-fourths of the weights, calculated as above, would be sufficient, especially where a sinker of the mushroom form is used, this form being very applicable to such situations.

A 10cwt. mushroom sinker, left for three or four weeks at the

bottom of the Medway, was found to have sunk completely into the mud, and it required very strong tackle and a mooring lighter to weigh it.

To facilitate search by a diver for an anchor or sinker at the bottom of a river, it has been found a good plan to paint it white.

Calculation of lateral pressure.

In order to calculate the lateral pressure, exerted on any mine by a given current, the following formula may be used.

$$P = 4{\cdot}085 \times V^2$$

where $V =$ the velocity of the current in miles per hour. From this equation P will be found in terms of pressure in lbs. per square foot of flat surface, which is nearly double that on the curved surface of a cylinder.

CHAPTER VI.

Mode of Ignition.

Having determined on the form of case, size of charge and mode of placing submarine mines in position, it next becomes necessary to decide how they shall be ignited, so as to do as much damage as possible to an attacking ship. This may be done either mechanically or by electricity.

Mechanical ignition.

First with regard to the mechanical mode of ignition.

Several arrangements have been tried with more or less success, by which charges of powder may be ignited by mechanical action. In several of the Confederate torpedoes which were raised from the bottom of the James River at Richmond, and the drawings and some of the originals of which I had an opportunity of seeing, through the kindness of Brigadier-General Michel, of the United States Engineers, a simple gunlock and percussion cap were used. These may be considered as among the most primitive contrivances of this nature, and from various circumstances, such as oxidation or incrustation on the metal in the more delicate parts, perhaps the least likely to act at the right moment. An improvement on this was the simple percussion system, by which a charge was ignited by the vessel herself striking directly on a cap containing a detonating mixture; the most delicate of these, mentioned by Captain Harding Steward in his *Notes on Submarine Mines*, appears to be Brook's fuze, which was arranged in the form of a nipple, projecting from the case containing the charge, formed of copper of different thicknesses, according to the amount of sensitiveness to be given, and primed with fulminate of silver. The details of this fuze are given in Captain Harding Steward's pamphlet already referred to, and need not therefore be repeated here. Several other forms of detonating fuze were also tried by the Confederates both for land and submarine service. An account of several ideas for mechanical ignition, devised from time to time, may also be found in the *Report of the Floating Obstruction Committee*.

Simple gun-lock.

Brook's fuze.

Singer's Torpedo.

One of the most successful of these was Singer's Torpedo. It was used extensively by the Confederates during the late war, and, while it proved very destructive to the Federal ships, it is stated, on good authority, that no accidents occurred in placing it in position. It is probable that considerable danger would still be incurred in clearing a channel studded with mines of this description, but if it can be moored without excessive danger to the men employed in such an operation, there is no doubt that it possesses an advantage well worthy of consideration. It consists of a conical shaped iron vessel, moored beneath the surface of the water by its smaller end. The lower part contains the powder charge and firing arrangement, while the upper portion is an air chamber, to give the necessary buoyancy. An iron bar passes, vertically, completely through the centre of the apparatus and projects at each end: on the upper extremity of this bar is an eye, through which the rope, used in the process of lowering the mine into position, is intended to pass: on its lower extremity, which protrudes some distance below the case, is another eye for the attachment of the mooring rope. In the newest form of this apparatus, ignition is effected by means of a friction tube, secured within the lower part of the case, made water-tight by means of a thin copper disc, soldered in; this copper disc, though thick enough to exclude water, is sufficiently thin to allow a pull to act effectually through it on the friction tube. This latter operation is effected by means of a loose metal cover, fitting on the top of the apparatus, and so arranged as to be thrown off if the case were pushed on one side by the contact of a passing vessel. This metal cover is connected with the ring of the friction tube by a chain, and directly its weight comes on this, the tube is pulled and the mine fired. The eye on the top of the central bar passing through the apparatus, protrudes slightly through a hole in the centre of the loose cover, and the rope, passed through this for the purpose of lowering the mine into its place, prevents the cover falling off during this delicate operation. In order, still further to guard against an accidental explosion, while placing the mine in position, a brass safety pin, fitting into a hole on the lower projecting portion of the central bar, is so arranged as to pass through a link of the chain, so that, in the event of the top falling off, the force of the jerk shall be taken up by this pin and not by the ring of the friction tube. A line, with a float attached to it, is connected with the safety pin, this float would drift away horizontally from the mine, when acted on by a current, and by it the safety key may be withdrawn at some distance from the apparatus, after the process of placing the latter in position has been completed. No difficulty or danger is said to have been incurred in thus rendering the mine active, and the recovery of the pin, at the end of the safety line, would give an unmistakable indication that the apparatus had

been put in active working order. This mine may be attached to an ordinary mushroom sinker, by a single mooring rope: this mode of mooring was adopted by the Confederates in practice.

Plate XIX. shows the general arrangement of the most improved form of this apparatus. *Fig.* 1 shows a half elevation and half section of the mine itself, with its mooring arrangements. *a* is the air chamber ; *b* the chamber to contain the charge; *c* the metal bar, passing through the centre, with a ring *d*, at its upper extremity to receive the slip rope used in lowering the mine into position, and a ring *e*, at its lower extremity for the mooring attachments. *f* is the friction tube, worked by means of the ring *g*, through the thin copper disc *h*. *i* is the loose metal cover, connected by a chain *k* with the ring *g* of the friction tube. *l* is the safety pin, shown also, in a side elevation, in *Fig*. 2. When the safety pin is in position, the chain *k* would be as shown by the dotted lines; after it had been drawn out, the chain would be released and the firing arrangement be free to act, as shown by the firm lines. *m* is the mushroom sinker by which the apparatus is moored.

Sulphuric acid or chemical fuze.

Another mode of mechanical ignition used by the Confederates, and previously by the Russians in the defence of the ports in the Baltic, is the well known sulphuric acid fuze, formed on the principle of ignition by sulphuric acid dropped upon a mixture of equal parts of chlorate of potash and loaf sugar. The sulphuric acid was placed in a small glass globule which was so arranged as to be broken by a blow, which would be given on touching the side of a vessel, and the acid thus set free, falling on the mixture of chlorate of potash and loaf sugar, produced the required ignition.

Captain Harding Steward gives an account of the attack of the United States frigate "Minnesota" by the Confederate torpedo boat "Squib," in which Captain Davidson, who was in charge of the latter, attributes the partial failure of his attack to the slow ignition produced by the chemical fuze, (sulphuric acid, chlorate of potash and loaf sugar), used: he supposes that, in consequence of this comparatively slow ignition, the torpedo boat had recoiled 3 or 4 feet before the actual explosion took place.

Improved chemical fuze.

There is no doubt that ignition by the sulphuric acid fuze is comparatively slow, that is to say slow as compared with that of gunpowder, but it may be very much improved by the addition of a small quantity of ferro-cyanide of potassium or sulphuret of antimony. From experiments made in the Chemical Laboratory at the School of Military Engineering, Chatham, it has been found that an addition of $\frac{1}{3}$ of ferro-cyanide of potassium, to the mixture of equal parts of chlorate of potash and loaf sugar, produces an ignition as rapid as that of gunpowder.

Sodium or

Another very simple mode of producing ignition has been

SINGER'S TORPEDO.

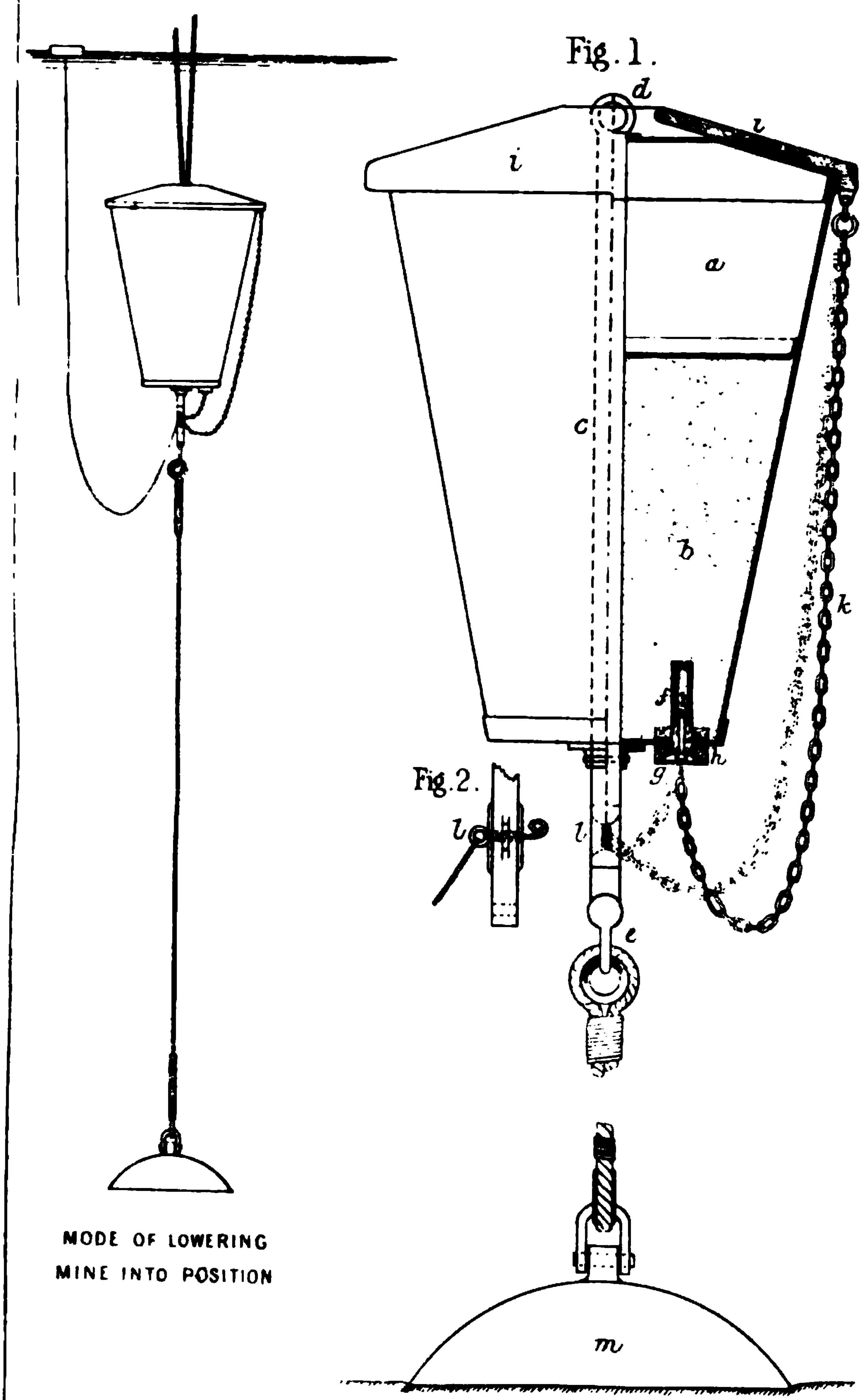


Fig. 1.

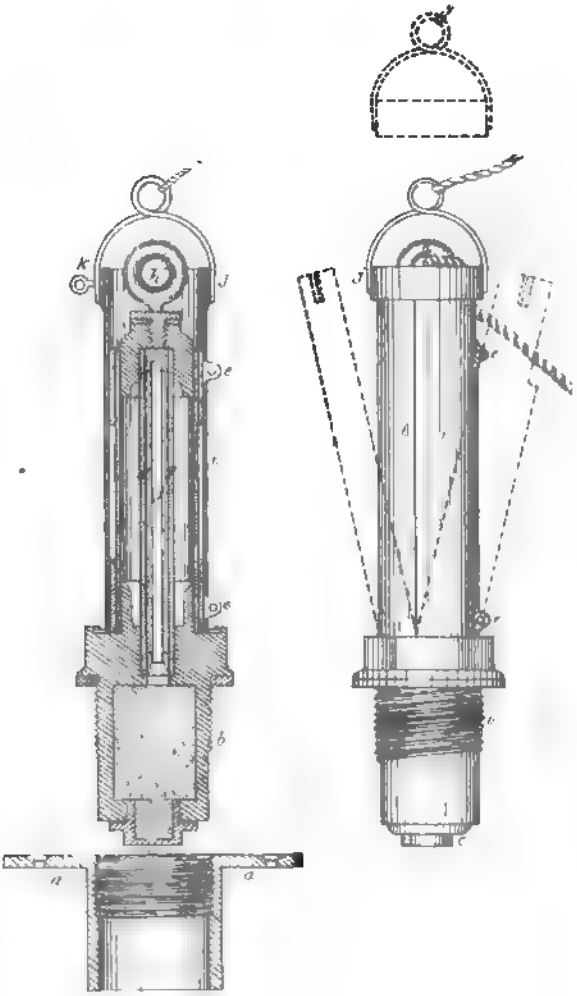
Fig. 2.

MODE OF LOWERING MINE INTO POSITION

Lithographed at the S M E. Chatham — B Butler. Corp' R E

PLATE XX.

ABEL'S TORPEDO-PRIMER.



Lithographed at the S M E Chatham

B. Butler, Corpl R E

suggested by Captain Campbell Hardy, of the Royal Artillery; it is simply caused by dropping water upon the metal sodium, when heat is produced. Potassium would also answer the purpose, but is inferior to sodium, the latter having a greater affinity for oxygen. Captain Hardy made several experiments with this substance at Halifax, Nova Scotia, with good results, the only fault he found with it was its comparatively slow ignition, which however, he thinks might be improved by piercing the body of the sodium with small holes. It would be well worth while making a few experiments with this substance, for even if the results obtained from it are not so good as those of the more approved forms of chemical fuze, it is so safe to handle that it presents many advantages which might be brought into use where other forms are not obtainable. The metal sodium can now be procured almost everywhere, in the form of a paste which is easily cut and manipulated. It must however be preserved in naptha or some substance containing no oxygen, or it would soon absorb oxygen from the air and become useless as an explosive agent. *potassium fuze.*

Abel's torpedo primer. The following description of an adaptation of the sulphuric acid fuze, arranged by F. Abel, Esq., F.R.S., Chemist to the War Department, has been approved by the Floating Obstruction Committee, and is extracted from their report.

"In *Plate* XX., *a* shows the socket to receive the primer, which is arranged to be fixed firmly on to the case containing the charge, as shown in *Plate* XXI.; *b* is the powder chamber to hold the priming charge, *c* is a screw nut closing the powder chamber; *d*, *Plate* XXI., a flexible indian-rubber tube, *e*, *e* are screw bands; *f* a lead tube containing the explosive mixture, *g* a glass tube containing oil of vitriol, *h* eye to receive the firing line, *i*, *i* guard in segments, *j* guard ring, *k* screw pin."

"Before the charge is placed in position, a cord or wire is attached to the eye of the guard ring *j*, and the screw pin *k*, in the side of the guard ring, is removed. When the primer is to be rendered active, after it has been placed in position, the guard ring *j* is removed by pulling the cord attached to it. When this has been accomplished, the guard *i*, *i* will fall away from the primer, leaving it active. The safety guard of the primer is on no account to be removed until the mine has been placed in the position assigned to it. When a sufficient strain is put upon the eye *h* the lead tube *f* bends, and the fracture of the glass tube *g* is thus determined, whereupon the primer is fired."

Primer socket. "The socket *a*, *Plate* XX., which is to receive the primer, and which accompanies it in the packing case, is fixed by means of screws or rivets into the opening of the vessel which is to be converted into a submarine mine. The usual precautions are to be taken to make the junction between the socket and the case water-tight. *Fair lead.* A piece of iron rod, about 12 inches long, is bent

at the end into the form of an eye: the other end is then screwed or driven into the case, in such a position that the rod is parallel to the primer when the latter is inserted in the socket (as shown in *Plates* XXII. & XXIII). In this operation, care is necessary to prevent the rod being so driven or screwed into the case, as to cause leakage under the pressure of water after submergance. The distance between the rod and the primer should be about six inches, and the eye of the rod should be about two inches lower than that of the primer. The nut at the base of the primer, *Plate* XX., is removed, and the powder chamber *b* is filled with gunpowder. The nut is then replaced and screwed down tightly, by means of the spanner provided for that purpose. The charged primer is screwed down as tightly as possible upon the washer, by means of the spanner. The position of the fixed primer is shown in *Plate* XXI. The firing line is passed through the eye of the rod, and is then firmly attached to the eye of the primer *h* as shown in *Plate* XXII. For this purpose the line must be passed through the hole in the guard provided in it, in order that the guard ring may be pulled away after the charge is under water. The connection of the firing line with a jackstay, or with the line of another mine, may be accomplished either before or after it is attached to the primer. A wire of copper or iron, or a small line coated with wax or pitch, sufficiently long to reach to the surface of the water, after the charge has been placed in position, is attached to the eye of the guard ring. The loose end of the wire should be attached to a small float, so that it may be recovered at any time. When the mine is ready to be submerged, the small pin *k* in the side of the guard ring is removed. This pin is not essential to the security of the guard, and may therefore, if thought advisable, be removed earlier. It is only provided to prevent the guard ring being removed by persons who may be needlessly meddling with the primer. If it is intended to leave the guard upon the primer some considerable time after it has been laid down, it will be advisable to lubricate the bearings of the guard upon the ring. For this purpose the screw pin is removed, the lubricating agent (grease or oil) is applied between the guard and the ring, and the latter is then twisted round two or three times, so as to ensure the lubrication of the bearings. This should be done, in every instance, before employing the primers, if they have been in store for some considerable time. Whenever it is intended to render the mine active, the guard ring is removed, by pulling the cord or wire attached to it; the guard will then fall away from the primer. By bringing the guard ring to the surface the operator will, therefore, know that the mine is in working order."

Charging primer.

Firing line.

Means of removing guard ring.

Lubricating guard ring.

Removal of guard ring.

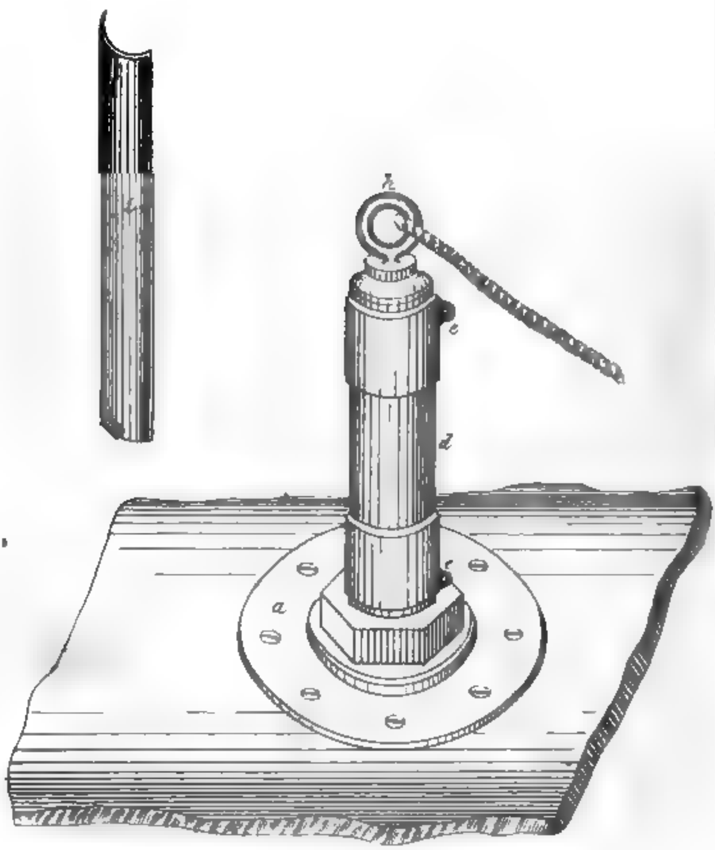
Different modes of arrangement

Abel's torpedo primer may be arranged for the ignition of a mine at will from the shore, by merely carrying a line from it, which may be pulled by hand when required, as shown in *Plate*

PLATE XI.

ABEL'S TORPEDO PRIMER,

FIXED IN CASE.

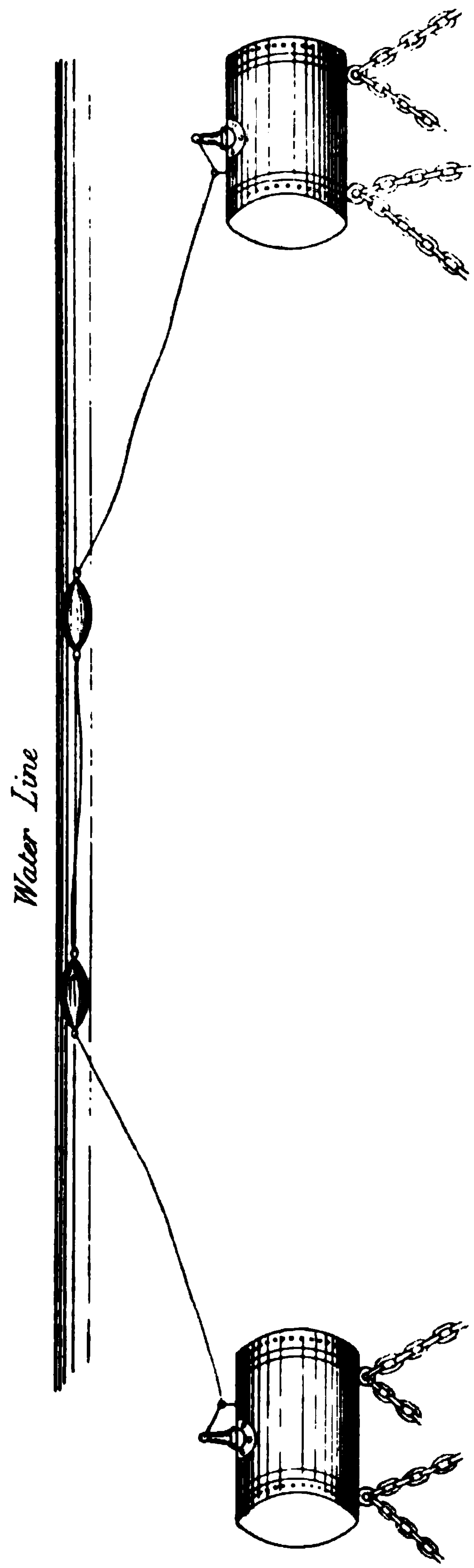


Lithographed at the S. M. E. Chatham. *B. Butler, Corpl. R.E.*

PLATE XXII.

PAIR OF SUBMARINE MINES.

FITTED WITH ABEL'S TORPEDO PRIMER.



Lithographed at the S. M. E. Chatham. *B. Butler, Corpl. R. E.*

SERIES OF SUBMARINE MINES,
FITTED WITH ABEL'S TORPEDO PRIMER.

Fig. 1

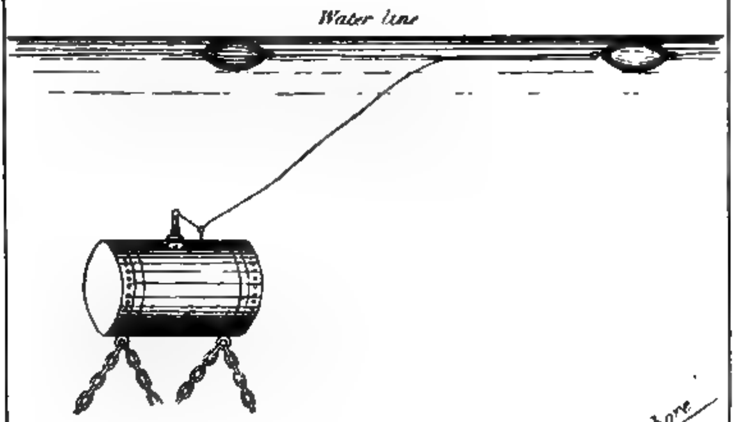
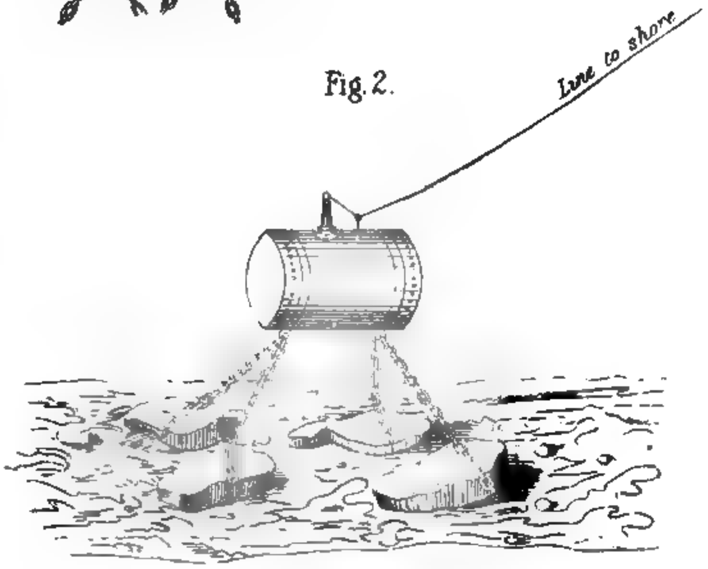


Fig. 2.



SUBMARINE MINE, FITTED WITH ABEL'S TORPEDO PRIMER,
TO BE FIRED AT WILL.

Lithographed at the S. M. E. Chatham

B Butler Corpl R. E.

XXIII., *Fig.* 2; or it may be fired by the contact of a passing vessel, as shown in *Plate* XXII. & *Fig.* 1, *Plate* XXIII.

for use with a mine.

It has been approved for service, and is now an article of store obtainable on requisition.

Defects of mechanical fuzes.

The great defect of all forms of self-acting mechanical fuzes, is the danger, almost inseparable from them, of accidental ignition: a blow given by accident in handling these affairs may produce a most disastrous explosion, and there is consequently a considerable amount of danger to be incurred in placing them in position, and still more in clearing them away. In the form recommended by the Floating Obstruction Committee, security is, to a certain extent, obtained by the metal coverings, which are not removed till the charge is actually in its place. Another method by which this very desirable object might be partially attained, has been suggested by Captain Harding Steward, R. E., of which the following is a description:—

Captain Harding Steward's safety stop-cock for mechanical submarine mines.

"It consists in the introduction of a stop-cock *k*, *Plate* XXIV., *Fig.* 1 at the head of the tube, between the fuze and the charge. This is so arranged that when the cock is turned in the direction of the tube, as in section *l*, the gas, on formation, can pass freely through and fire the charge. When the cock is shut off, the gas, on a fuze exploding by accident, is made to escape by the side as at *m*, a cut at right angles to the main cut in the cone being provided for that purpose."

Destruction from leakage of water is one of the chief dangers to which this arrangement would be liable, when the stop-cock is turned off. It is to be observed, however, that it would only be turned off when at or near the surface of the water, where the pressure is least, and turned on when submerged and the water pressure greatest, the chance of leakage being, however, least under corresponding circumstances. In order to prevent the leakage in question, Captain Steward has made the following provision:—

"The cone, in connection with the stop-cock, should be ground to fit very accurately, in order to prevent leakage of water; and in addition, it is proposed to cover the escape hole with a small waterproof plaster which, at a moderate depth where the pressure of the water was not too great, would keep the water out, while at the same time it would offer no material resistance to the exit of the gas, if the stop-cock were turned off for safety."

"It is presumed that mechanical submarine mines would have guards or covers of some sort to protect the fuzes, and with the stop-cock in addition, which guarantees cutting off the priming from the charge, a detonating mine, however delicate, could be transported in a boat to the point of deposit, buoyed on the surface and the moorings properly regulated for submerging without incurring any danger of an explosion. The fuze guards would probably have to be removed prior to launching the mine

over the side of the boat, but the stop-cock could be left turned off till everything was ready for submerging—until then no greater mishap than the destruction of a fuze could occur, even if accidentally struck."

A few experiments have been made in the School of Submarine Mining at Chatham, with this arrangement, and it was found to cut the gas off from the charge quite efficiently in every case, as far as safety was concerned. It has not, however, been tried under water to test its capacity to withstand leakage.

Captain Steward's proposed mode of mooring mechanical mines.

Captain Steward suggests, as a further preventive against accident, that "three moorings should be used for buoyant mechanical submarine mines. If two moorings were, in the first instance, established at low water, the case might be allowed to float, as shown, *Plate* XXIV., *Fig.* 2; a third mooring should then be laid out, in the direction of the current, and the mine drawn down thereto, which would bring it into the position shown at *Plate* XXIV., *Fig.* 3." It is to be observed that this mode of mooring (with three cables) is not so objectionable with a mechanical mine as it would be with one fired by electricity. There being no electric cable, in connection with it, to be wound up or injured, no necessity exists for preventing it turning to any extent, and it might be supplied with a swivel at its apex to admit of its turning, as is often done with the ordinary buoys used for marking a channel.

"To raise a mine thus deposited, the case could be brought to the surface, at low water, by raising the stream mooring, and bringing it forward a little."

On raising a mine it might be made quite safe, by simply turning off the stop cocks the moment it came to the surface.

This arrangement for shutting off, as it were, the fuze from the charge of powder, is applicable to almost any form of mechanical ignition that may be devised.

Prussian mechanical submarine mines.

During the late war of 1870-71, the Prussians made great use of mechanical submarine mines. These were generally placed on the flanks of their electrical mines, which latter were employed for the defence of navigable channels, while the former were intended to defend positions which were to be entirely blocked up. These Prussian mechanical mines consist of a conical case made of $\frac{3}{32}$-inch galvanized iron plate, in three portions, the top, the body and the bottom, securely riveted together, with water-tight joints and straps to strengthen the whole and preserve rigidity. Each possesses a capacity for 70lbs. of gunpowder and, when loaded, has a buoyancy of 100lbs. The top is convex and on it are placed five percussion nipples, one in the centre and four at equal intervals round the shoulder of the cone. The moorings are attached to the apex of the cone, which thus floats base uppermost when in the water. The Prussians have hitherto employed two kinds of percussion nipples, or fuzes, which are

SUGGESTIONS OF CAPTAIN HARDING STEWARD, FOR MOORING MECHANICAL MINES WITH SAFETY.

Fig. 1.

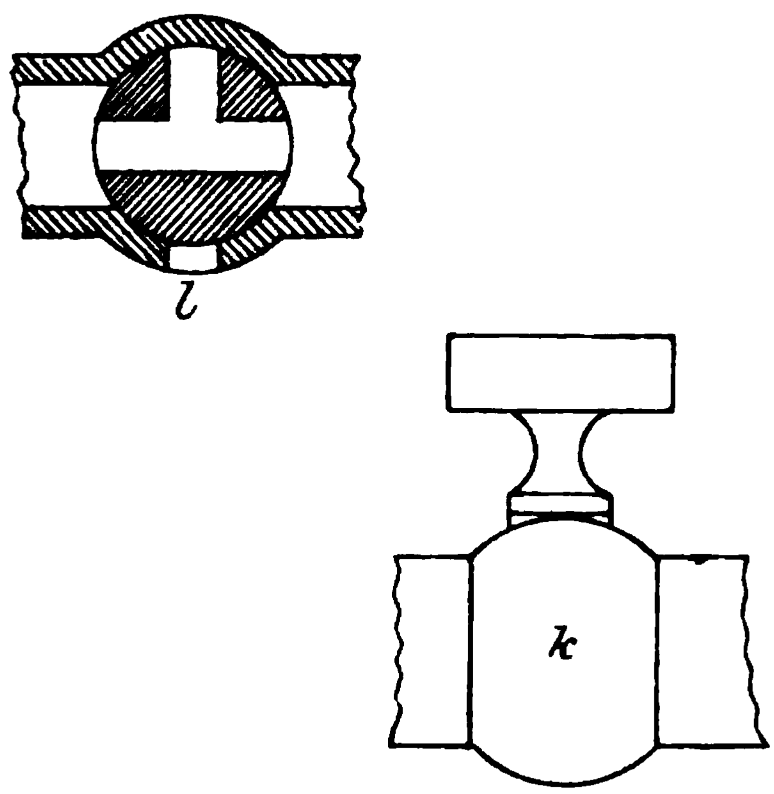
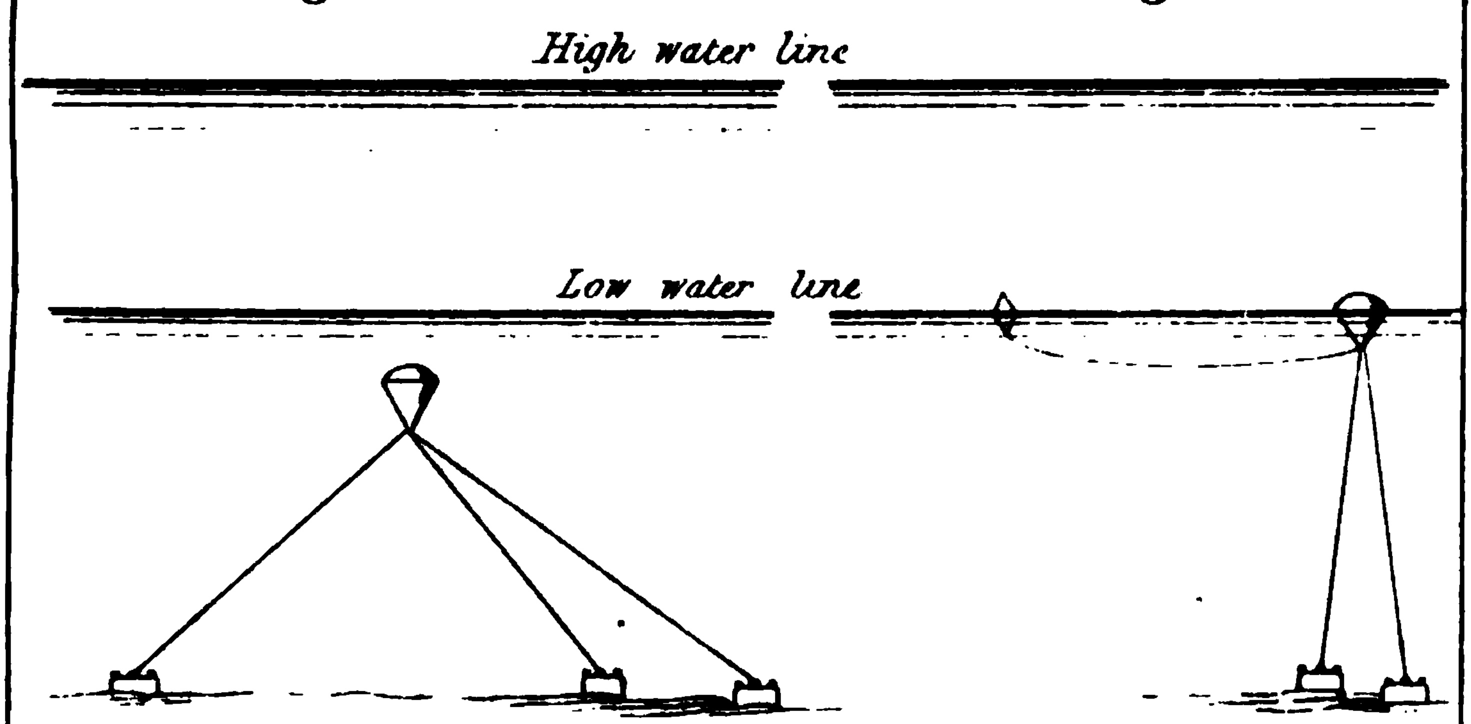


Fig. 3. Fig. 2.



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B Butler, Corp^l R.E.

screwed, with washers to make them water-tight, into places prepared for them, in proper position, in the head of the case.

Prussian percussion fuze.

The first of these nipples consists of a very brittle metal arm, composed of an alloy of tin and lead, which has a small knob at its outer extremity, while its inner end is screwed, through a gun metal collar, and into a sharp pointed striker, immediately over an ordinary percussion cap: the brittle metal arm acts against a spiral spring, between the striker and the gun metal socket, by means of a shoulder which rests upon the upper part of the latter. Ignition is effected by means of an ordinary percussion cap, against which the striker is driven down sharply when released. In connection with the percussion cap is a priming charge, arranged to communicate with the main charge in the interior of the mine. Over the brittle metal arm is a thin metal cap, to keep the water out and through which a vessel striking the mine would act. On a vessel striking this nipple, the brittle metal arm is broken off at its weakest point, below the shoulder, releasing the striker, which is driven sharply down upon the percussion cap by the spiral spring and the charge fired. A thick metal, safety, guard cap is screwed on over the whole and is only removed just before the mine is finally lowered into position. This fuze is said to be very sensitive, but care must be taken to leave a sufficient distance, between the mines of a group in which it is used, as the sudden jar of an explosion has the effect of breaking off the brittle metal arm, as shown by the experiments.

Prussian chemical fuze.

The second fuze used by the Prussians is a chemical fuze. It has the same external guard and thin metal cap as the percussion fuze. Within the thin metal cap is a long glass tube, hermetically sealed at both ends, containing sulphuric acid, enclosed in a thimble-headed tube of lead, the space between the glass and leaden tube being filled with a mixture of chlorate of potash and loaf sugar. One end of the leaden tube is fixed firmly into the lower part of the fuze, in connection with a priming charge of powder, communicating with the interior of the mine; the other extremity fits very tightly into the interior of the thin metal cap, so that a very slight blow from a passing vessel would break the glass tube and release the sulphuric acid, which falling on the chemical mixture would produce heat and fire the powder priming and, through it, the mine itself.

Dummy mechanical mines used for drill and instruction.

Much dexterity is required in putting mechanical submarine mines in position, in order to prevent accidents with these very dangerous machines. For instruction and drill purposes, the Prussians employ dummy mines, made of wood, with places to receive the fuzes as well as the mooring gear, as in the real apparatus. Notwithstanding the utmost care, and previous preparation and careful training of the men employed, several serious accidents occurred in placing these mechanical mines in position.

Mechanical

Quarter-Master Sergeant J. Mathieson, R.E., has suggested a

mine, suggested by Q.-M. Sergt. Mathieson, R.E.

form of mechanical submarine mine, combining certain ideas, intended to secure the very important element of safety in placing these machines in position. This is shown, in section, in *Plate* XXV. It is intended for a charge of 100lbs. of compressed gun-cotton, and consists of a case *a* of No. 15* B.W.G. galvanized sheet iron. *b* is an iron band, 2 inches by ½-inch, with lugs, similar to those already described for the approved forms of case, screwed on in the usual way: the attachment chains would be connected to the lugs, as already described, for mooring purposes. *c* is a wooden shoulder, 9 inches by 6 inches, to receive any blows to which the mine might be subjected; it is secured to the case by an iron band passing round it. *d* is a brass mouth piece, screwed into an opening provided in the top of the case, a shoulder of solid metal being rivetted on at this point to receive it. *e* is a brass tube, into which a hermetically sealed glass tube, containing sulphuric acid would be dropped when it is intended to put the mine in action against an enemy: the lower part of this brass tube would contain a chemical mixture, of chlorate of potash and loaf sugar, and it is terminated by a long conical portion *f*, containing a priming charge of fulminate of mercury, and made of such size as to fit tightly into the gun-cotton disc *g*. *h* is a perforated brass guard, covering and protecting the fuze and gun-cotton disc. *i* is the exploding hammer of lead, resting on, but not attached to, an indian-rubber disc in the top of the case. *j* is a dome of perforated cast iron, screwed on to the top of the case, to protect and cover the hammer *i* and brass tube *e*. A sufficient amount of buoyancy is provided, by allowing a certain amount of air space in the top of the case after the charge of gun-cotton has been put in: the dimensions shown admit of this. *l* is an indian-rubber tube, at the extremity of which is a copper float *m*, 6 inches in diameter, by means of which it is proposed to drop the hermetically sealed glass tube, containing sulphuric acid, into its place after the mine is in position. It is supposed that the mines would be laid out at low water; when all the mooring arrangements are completed, it is intended to insert the glass tube in the outer extremity of the indian-rubber tube, screw on the float and leave it. It is supposed that the float would rise with the tide, and let the glass tube slip gently into its place in the brass tube *e*. *r*, *r* are screws, passing through the perforated iron guard *j*, and into the hammer *i*, by which the latter would be kept in its place, and prevented from striking the brass tube *e*, if accidentally struck in handling or moving the case: the screws *r*, *r* would be removed immediately before lowering the mine into position.

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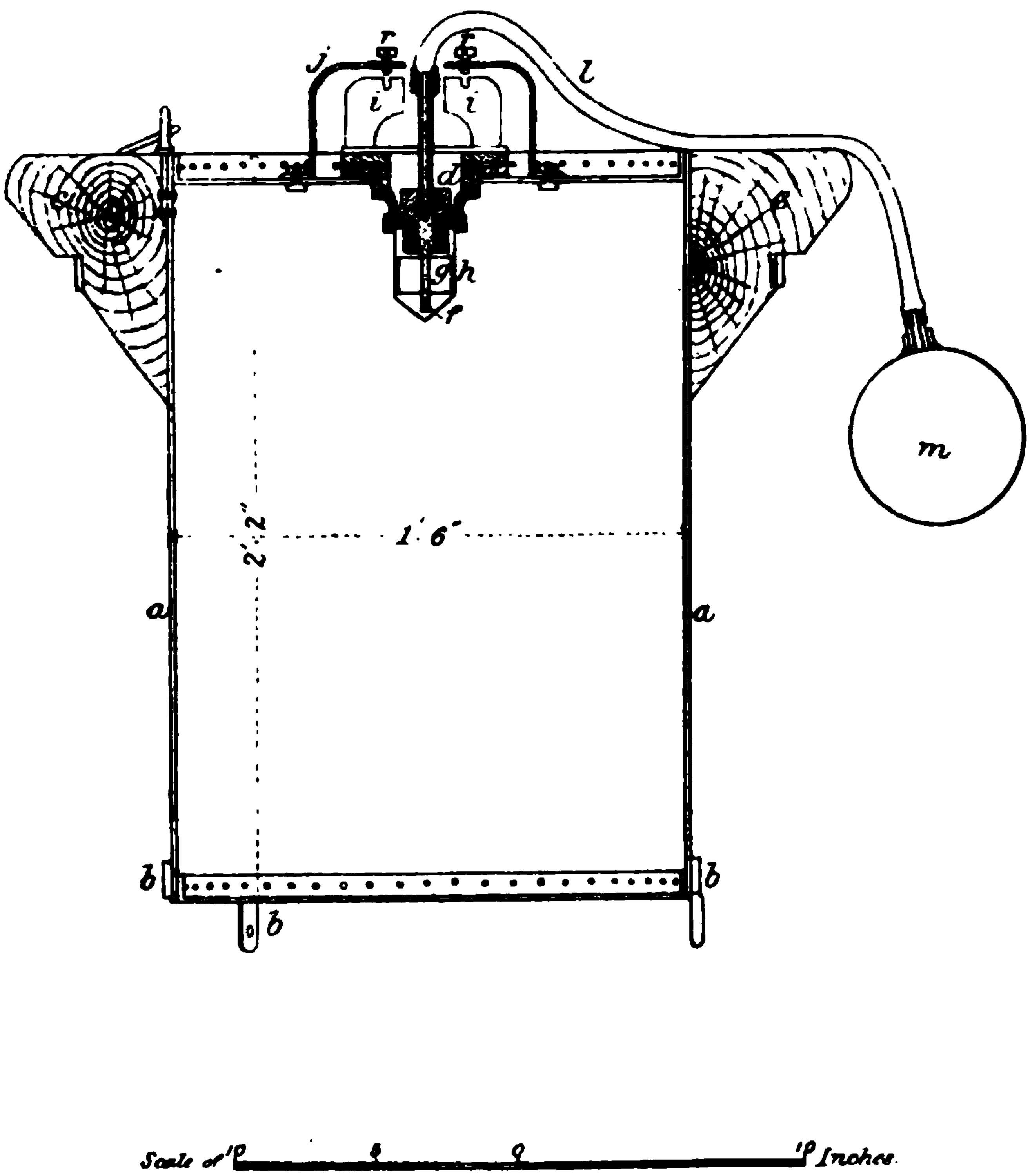
* The usual 100lbs. cases are of No. 12. B.W.G. sheet iron, tinned, and it would probably be convenient to use this thickness of plate for all charges to contain 100lbs. of gun-cotton.

MATHIESON'S SAFETY MECHANICAL SUBMARINE MINE.



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The action of the firing hammer *i* is due to its inertia: being very heavy it would remain stationary till the case itself is struck, but on the latter receiving a blow, the hammer would be brought in contact with the brass tube, with ample force to break it and the glass tube contained within it. Experiment has proved that the mine may in this way be fired with certainty, by a comparatively light blow. *Mode of action.*

This apparatus has yet to be tried. The use of the small float *m*, which must always be visible at low water and for a considerable period after the tide has begun to rise, is objectionable, as by its appearance it would reveal the position and nature of the mine to an enemy. It would be desirable, if possible, to make all contact mines, as well as dummies, in fact every variety of apparatus that is likely to be visible occasionally at low water, as similar as possible to each other in appearance. It is very desirable to moor or remove mechanical submarine mines of all classes in calm weather.

To clear a channel, Qr.-Mr. Sergt. Mathieson proposes to approach the mines when the buoys are just awash, to unscrew the buoy and draw the glass tube out by means of a line attached to its upper extremity. The indian-rubber tube being four feet long, he supposes that there would be at least three feet of water over the mine, when the buoy was just awash, and that it might be safely approached by a boat drawing a foot of water. Should the operation of drawing out the glass tube be considered too dangerous, it would only be necessary to fire at the buoy with a rifle and thus admit water and drown the charge, after which it could, of course, be taken up with safety. The fact that a perforation of the buoy would admit water and drown the charge, is decidedly against its use, as an enemy would no doubt soon become acquainted with the fact, and act accordingly. *Mode of clearing a channel.*

Qr.-Mr. Sergt. Mathieson has also proposed for submarine mines of the form designed by him, in lieu of the tube and buoy, a self-acting locking arrangement, acted on by a lever in such a manner that, when a mine is submerged, the lock is withdrawn and the machine made active, under the influence of its own floatation, when just under water. In connection with this idea, he proposes to draw the mine down, by means of a rope passing through the centre ring of a mushroom sinker, which operation could be performed at some distance, horizontally, from the charge itself; and, having brought it to the required depth, to secure the hauling down gear, in such a manner as to hold it there. This latter scheme gets rid of the ball buoy, which seems an advantage. To recover a mine provided with such a lock, it would only be necessary to release the mooring gear and let the mine come to the surface, when the self-acting apparatus would lock the firing arrangements and render the mine safe to handle. *Self-acting locking arrangement for mechanical mines, proposed by Q.-M. Sergt. Mathieson.*

None of these ideas have yet been sufficiently tried to enable

a decision on their merits to be arrived at, but some device of this nature is essential, to enable mechanical mines to be handled with a moderate amount of safety, and it is to be hoped that something, in the direction indicated, may be found to prove effective.

Electrical ignition.

Passing from the mechanical, we now come to the electrial mode of ignition, in which the fuze is a very important item.

Several forms of electric fuzes have been devised and used for the ignition of gunpowder, gun-cotton, &c. The Confederates used the platinum wire fuze and Grove's or Bunsen's battery, in many of their mines which were arranged to be fired by electricity. This form of fuze, in connection with the first named battery, has for a long time formed a part of the Engineer Equipment of the British Army for land mining operations, and the result of some experiments with it, in connection with submarine mines, has been so successful that it could no doubt be effectively used for the latter purpose.

Platinum wire fuze.

Advantages of the platinum wire fuze.

There are numerous advantages to be derived from the use of the platinum wire fuze, of which the following are the principal:—

1st.—Great facilities are afforded for testing the fuze, which presents, moreover, a very small electrical resistance, which resistance is not liable to alteration, in consequence of the nature of the metal of which it is composed.

2nd.—It does not deteriorate by climate, &c., and can be stored for any length of time without damage.

3rd.—It can be very easily improvised, and the materials, of which it is composed, are simple.

4th.—It does not require the very high insulation, in the conducting cable, which is necessary when a fuze, fired by a current of high tension, is used: and it may be fired through a cable in which a comparatively large fault exists.

5th.—There is no danger of an accident during the process of testing, for which purpose more powerful batteries, of Daniell's or any other suitable form, may consequently be safely used. Considerable care is necessary in testing high tension fuzes generally, as will be demonstrated hereafter.

It has been ascertained by experiments carried on in the river Medway, opposite Gillingham, that in sea water a return wire is not necessary, and that even earth plates of any considerable size are not essential, when using the fuze in connection with Grove's battery; fuzes have been successfully fired with earth connections formed of a few inches only of bare wire, with the addition of a comparatively small number of battery cells over the number necessary with a return wire or ordinary earth plates.

The following is a short account of the experiments tried:—

Experiments with platinum fuze and

1st.—In order to test the fusing power of the battery, a platinum fuze, represented by $\frac{3}{10}$ inches of platinum wire, in a thermo-galvanometer, was placed in circuit with a length of cable, composed of Hooper's core with a conductor consisting

of a strand of 7 No. 22, B.W.G. copper wires, and without a return wire. One pole of the battery was connected, by a short length of No. 12, B.W.G. copper wire, with the copper sheathing of a mooring lighter, the outer extremity of the cable being soldered on a tin case 2ft. 6in. high and 2ft. 0in. in diameter, to form the other earth connection: this tin case being about 100 yards from the lighter. The electric resistance of this cable is 10 ohms, nearly, per statute mile, and was 4 ohms, nearly, for the length employed; that of the fuze ·24 ohms, rising to ·8 ohms at the moment of fusion, and that of the small length of No. 12, B.W.G. copper wire, connecting the circuit to the copper sheathing of the lighter, would be about ·2 ohms. With this combination $\frac{3}{10}$ inches of platinum wire, weighing 1·6 grains to the yard, were fused with six cells of Grove's battery, of the ordinary military pattern. A second length of a similar cable having been added to the conductor, increasing the cable resistance in circuit to 6 ohms, nearly, $\frac{3}{10}$ inches of platinum wire were fused with eight cells: on a third length of cable, increasing the total electrical resistance of the cable to about 10 ohms, being added, the platinum wire fused with 13 cells.

Grove's battery.

This experiment proved that, with this form of battery and fuze, a return wire is unnecessary, and that an increase in the length, and consequent electrical resistance, of the conductor does not necessitate a very large proportionate increase of battery power.

Distance between earth plates, in sea water, no objection.

2nd.—In order to ascertain whether an increase of distance between the earth plates in any way altered the conditions of the case, the tin can, forming the outer earth plate, was moved to a distance of rather more than 500 yards from the lighter, and connected with a conductor, of about 10 ohms resistance, the electric cable being veered out for this purpose. With this combination $\frac{3}{10}$ inches of platinum wire were fuzed with 12 cells, and in a second trial with 13 cells of the battery, thus proving that there was no additional resistance interposed by the increased intervening mass of water, or, in other words, that the water resistance was practically nil.

Experiments to determine the minimum of earth connection with Grove's battery and platinum fuze.

3rd.—Further experiments have been tried with Grove's battery, and the platinum fuze, to determine the minimum of earth connection, requisite effectually to fuze the platinum wire, without inordinately increasing the number of battery cells.

With a conductor, consisting of a cable, of about 4 ohms resistance (Hooper's Core, similar to that used in former experiments), and $\frac{3}{10}$ inches of platinum wire in a thermo-galvanometer to represent the fuze, the following results were obtained:—

No. of Cells to produce fusion.	Extent of earth in inches of bare wire.
6	24
7	15
8	6

No. of Cells to produce fusion.	Extent of earth in inches of bare wire.
9	$3\frac{1}{2}$
10	3

One pole of the battery was, on this, as on the former occasion, attached to the copper of the mooring lighter as an earth plate.

With a cable of about 6 ohms resistance in circuit and similar arrangements to the above, the following results were obtained:—

No. of Cells to produce fusion.	Extent of earth in inches of bare wire.
20	$\frac{3}{4}$
20	$\frac{1}{2}$

the latter failed to fuse, but heated the platinum wire to redness.

The result of these experiments shows, that earth plates of the ordinary size will answer every purpose, when used in connection with Grove's battery and the platinum fuze, for submarine mining purposes.

Increase of fusing power produced by the sudden reversal of the poles of a battery.

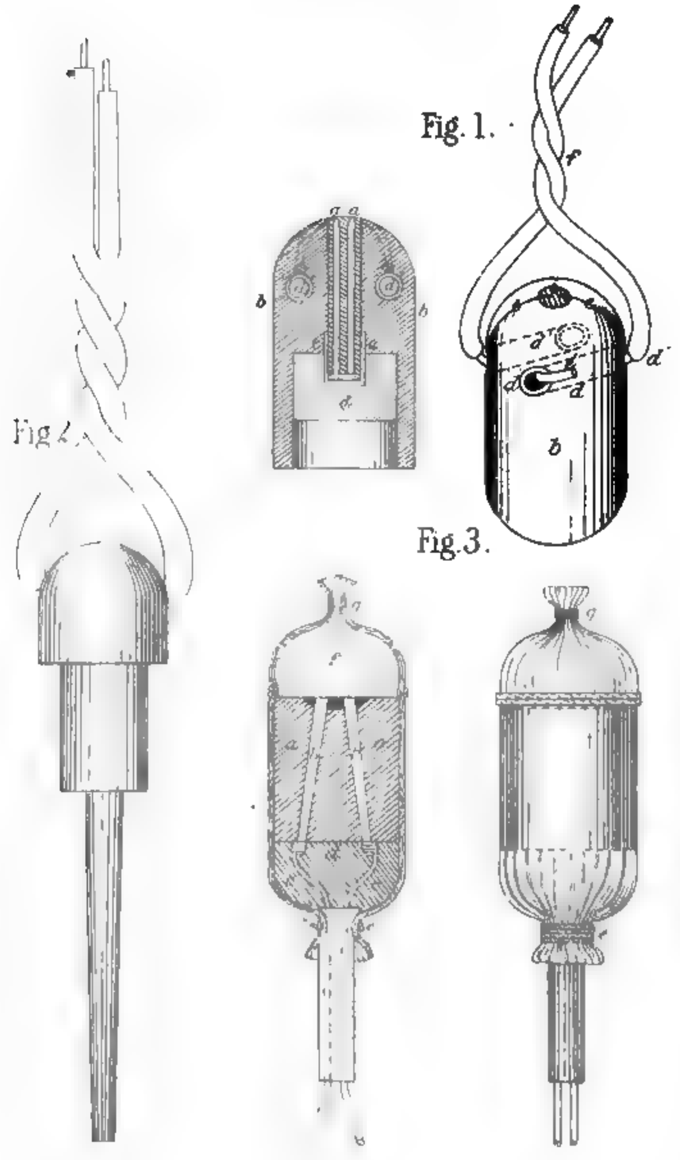
Mr. Brown, of the Chemical Department, Royal Arsenal, gives the following information, as the result of some experiments made by him with Grove's battery and the platinum fuze:—He finds that the best results were obtained by suddenly reversing the poles of the battery—that is to say that a fuze, which will not fire with a given number of cells of a battery, may be successfully fired by simply reversing the poles of the same battery. The reason of this is that, by keeping a battery current constantly circulating through any given combination, in which the earth plates are exposed in sea water, these earth plates, or any metalic substance in the circuit, in contact with the sea water, become coated either with sub-chloride of its particular metal or with hydrogen, which partially insulates the exposed surfaces and, moreover, starts a distinct battery action which is in opposition to the the original current and therefore assists the reversed current. A sudden reversal of the poles of the battery dissipates these combinations for a time, that is to say, till they again form by changing places, as it were, on the opposite earth plates, to those on which each was originally deposited. This mode of firing is not desirable in practice, and is only mentioned here as a record of the results obtained. For actual work it would always be necessary to use a considerable excess of battery power.

Platinum wire fuze for submarine mines.

The platinum wire fuze, used for submarine mining purposes, is precisely similar in outward form to that shown in *Plate* XXVI., *Fig.* 1. The only difference is, that the bridge consists of $\frac{3}{10}$ in. of thin platinum wire, weighing 1·6grs. to the yard, instead of the chemical mixture employed in Abel's original mining fuze. This platinum wire is soldered* on to the wire

* Difficulties have been experienced in soldering the fine platinum wire on the fuze terminals, and it has not yet been finally decided whether it shall be so soldered or attached in some other way. Soldering would, of course, be electrically preferable, as giving the best connection.

ELECTRICAL FUZES.



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points in connection with the fuze terminals, inside the wooden fuze head, and is in contact with the priming, which would be 20grs. of mealed powder, for the ordinary and 15grs. of fulminate of mercury for a detonating fuze. In the latter case the fulminate would be enclosed in a long, conical, tin case, in order to fit tightly into the gun-cotton priming as shown in *Plate* XXVI., *Fig.* 2. The wooden head of the platinum wire fuze is painted white, for the sake of distinction. In the official Woolwich vocabulary, the platinum wire fuze, primed with powder, which is used only for experimental purposes is designated "No. 3. Fuze, electric, platinum wire," the service platinum wire fuze is called, "No. 7. Detonator, electric, platinum wire," and is used in connection with gun-cotton priming, the long, conical ends being pushed into the holes left for them in the gun-cotton priming discs, into which they should fit very tightly. Close contact is essential, in order to produce the necessary detonation at the moment of ignition. The platinum wire fuze is intended to be used in connection with the 100lb. electro-contact mines and Mathieson's disconnector: a series of mines may be put out, in connection with a single electric cable, on this system in a manner which shall be hereafter described.

Gun-cotton priming forms a very sensitive fuze.

The following experiments, carried on by Lieutenant Bucknill, R.E., prove that gun-cotton priming has the effect of rendering the fuze more sensitive than gunpowder, as it ignites at a much lower temperature.* With a conductor of an insulated cable, (Hooper's Core, as previously described), the electrical resistance of the cable being, about 10 ohms, an ordinary platinum fuze, as made in the School for Land Mining, primed with gunpowder, fired with 12 cells of Grove's battery, and the platinum wire fused with 13 cells. A platinum fuze, designed by Lieut. Bucknill, for submarine mining service, and which, though differing considerably in form, was not very different in principles and construction from the service platinum wire fuze, was next tried. With the same insulated cable, the electrical resistance of the cable being, as before, about 10 ohms—

Gun-cotton priming fired with 6 cells.
Mealed powder „ „ 11 „
Cotton and powder mixed „ 7 „

With a shorter conductor, the electrical resistance of the cable being about 4 ohms, the following results were obtained—

Gun-cotton priming fired with 2 cells.
Mealed powder „ „ 4 „
Cotton and powder mixed „ 2 „

With the same cable (4 ohms) and a leak of one foot of bare wire in the conductor—

Gun-cotton priming fired with 4 cells.
Mealed powder „ „ 7 „

* This fact was fully established by the results of experiments made by Wheatstone and Abel in 1856.

With the same cable (4. ohms) and a leak of 2 feet of bare wire—

Gun-cotton priming fired with 5 cells.

Mealed powder „ „ 8 „ (slowly)

With a conductor of 6 ohms of cable resistance and a leak of 2 feet of bare wire—

Gun-cotton priming fired with 9 cells.

Mealed powder „ „ 15 „

In one case of mixed powder and cotton, the powder did not surround the cotton, and the latter ignited without firing the former. It is therefore necessary to embed the cotton well in the priming powder, and no failure has ever occurred when this was properly done. The earth connections used during these experiments were the same as those employed before, viz., the copper sheathing of the mooring lighter at one end, and a cylindrical tin case, 2ft. 6in. high and 2ft. 0in. in diameter, at the other.

Electric battery for use with platinum fuze.

In order to fire a charge by means of the platinum wire fuze, a battery producing a current of large quantity must be employed, ignition being produced by heating the piece of fine platinum wire, in the circuit, to fusion, by the passage of the electric current. Grove's, Bunsen's, Walker's, or Smee's batteries are among those suitable for this purpose.

Grove's battery.

The experiments above recorded were carried on with Grove's battery, of the form adopted for land mining in the British service. A detailed account of this battery may be found at page 138, paragraph 295 of *The Course of Instruction in Military Engineering*, and the paragraphs following, and the reasons for its adoption are recorded in an article, by Captain (now Colonel) Ward, R.E., in Volume IV. of the New Series of the *Professional Papers of the Corps of Royal Engineers*. Grove's battery possesses the defect of inconstancy: that is to say that, after having been in action or even mounted and ready for use for a comparatively short time, the active force of the current is considerably diminished, and in time it would no longer possess the power to fire a platinum fuze. From experiments tried at Chatham it has been ascertained that, when used under similar conditions to those for which it would be employed as an agent for submarine mines, 24 hours is about the limit up to which it will perform its work with certainty. If adopted for this purpose, therefore, it would be necessary to take it to pieces, clean and remount it every 24 hours. In consequence of this defect, experiments have been instituted with other forms of batteries, with a view of obtaining a constant voltaic battery to fulfil the conditions required.

Defects of Grove's battery.

Walker's battery.

Platinum wire may be fused by means of Walker's zinc-carbon battery, which has the advantage over Grove's battery of being very much more constant. When not in action it may be allowed to remain mounted for weeks together, without any considerable reduction in the strength of the working current, and has proved

itself so efficient, not only in connection with the platinum wire but with the high tension fuze, that it has been decided on as the service firing battery for submarine mines. It has been found desirable, to keep the plates out of the liquid till the moment of action, and special arrangements have been made for suspending them over the cells, in such a manner that they may be lowered very quickly into these latter, when the battery is required for use: the cells always hold the liquid, ready for work at a moment's notice.

Mr. Walker states that he has fused $\frac{3}{10}''$ of platinum wire, of 1·95 grains to the yard, with 6 cells of a battery of this form, composed of plates 2" wide and 3" immersed in diluted sulphuric acid (1 of acid to 8 of water), with 7 or 8 cells the wire is fused better, and with 9 it works very well. The plates of the battery used by Mr. Walker are comparatively small, and consequently a large number of cells of this size is required to produce the same result, which would be obtained from two cells of the service pattern, portable form of Grove. In order to test the efficiency of this battery, therefore, an experiment was tried in the Telegraph School, Chatham, by combining together a number of plates of Walker's battery, so as to form two large cells. By arranging in this way, so as to obtain an immersed surface of 140 square inches of zinc, we were just able with two cells to fuze $\frac{3}{10}''$ of platinum wire of 1·95 grains to the yard. This surface of 140 square inches was easily obtained, in a compact form, by giving the plates a cylindrical or perhaps better, for the more easy manipulation of the carbon, a polygonal form, on which latter plan they have been made with a diameter of 4½in., and height of 8in., extreme outside measurement, for each element of the battery. A few large cells, of this form of battery, were accordingly procured for experimental purposes, and the results obtained with them proved so promising, that further investigations were made, which finally resulted in the adoption of a battery of Walker's form for firing submarine mines. The service battery is a modification of the large cells originally tried, and in it the working power required is produced in a somewhat different manner from that originally designed. The size and arrangement of plates and special fitments decided on, shall be described hereafter in detail.

Electric fuzes for use with current of high tension.

The platinum wire fuze, in its simplest form, (not the very perfect form above described), is not complicated, and may be very easily made at any time, but in consequence of the apparent defects, which have however since been to a great extent overcome, as regards the battery for use with it, and the great advantages which undoubtedly exist under certain circumstances, and especially in land mining operations, in the use of electric fuzes, capable of being fired by a current of high tension in contradistinction to one of large quantity, which latter, as produced

by Grove's and other batteries, is necessary for use with the platinum wire fuze, efforts have, from time to time, been made to produce a good high tension mining fuze.

Beardslee's fuze.

One of the more recent of these, invented by Mr. Beardslee, of New York, consists of a cylindrical piece of soft wood, about $\frac{3}{4}$-inch in length, and about $\frac{3}{4}$-inch in diameter, shown at *a*, *Plate* XXVI., *Fig.* 3, through which two copper nails *b*, *b*, are driven home in a slanting direction, so that, whilst the two heads come as close together as possible without absolutely touching, the pointed ends are at some distance apart from each other, and project below the wooden cylinder. To these ends are soldered the bared terminals of two insulated copper wires *c*, *c*, and a piece of soft wax *d*, of the same size as the wooden cylinder, is pressed round the points of junction. A groove is made with a file across the heads of the copper nails, into which is rubbed a little blacklead from a pencil.* Round the wooden cylinder are now wrapped several folds of paper, forming a cylinder about $2\frac{1}{2}$ inches in length, one end being tightly fastened with a string round the insulated wire at *e*. This paper cylinder is then filled with a mixture of very fine grain and mealed powder *f*, and the end *g* is choked with twine. The entire fuze is afterwards coated with black varnish. This fuze is only applicable with certainty, when magneto induction exploding instruments, (or battery power suited to it), are employed. It would rarely be fired by a frictional machine.

Von Ebner's fuze.

Another form of electric fuze, for mining purposes, is the Austrian, invented by Baron Von Ebner, General of the Austrian corps of Engineers. Its construction is shown in section in *Plate* XXVII., *Fig.* 1, *a* is a thin copper wire, about No. 22 gauge, on which a core *b*, composed of a mixture of ground glass and sulphur, is formed, in such a way as to insulate the two portions of the wire, within the core, from each other. The wire *a* is originally in one continuous length, and after the core has been formed on it, a small opening *c* is carefully filed through, to form a break with a minute interval in its electrical continuity, A small copper cylinder *d* is now pushed on over the core, and a further quantity of ground glass and sulphur *e*, *e* is put round this latter, to secure the cylinder in its place. This mixture of ground glass and sulphur has been substituted for gutta percha, which was used in the original Von Ebner's fuze, because the latter becomes soft by heat at a very moderately high temperature, if exposed to the heat of the sun, for example, and the wires *a*, *a* would be in danger of being pushed into contact, which would be fatal to

* A minute quantity of some substance, which importantly assists the blacklead in its action, is applied to the wood in addition to the blacklead in the fuzes of Mr. Beardslee's own manufacture. The nature of this substance has not been disclosed.

ELECTRICAL FUZES.

Fig.1.

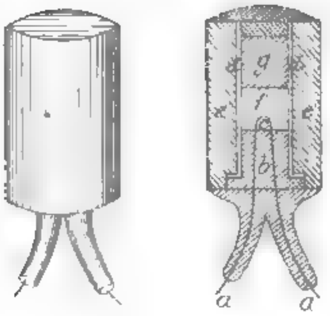


Fig.2.

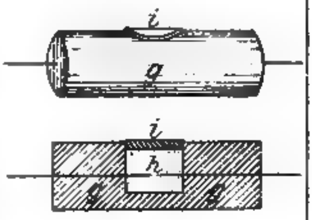


Fig.3.

Fig.4.

Fig.5.

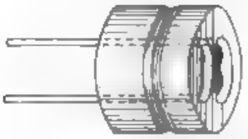
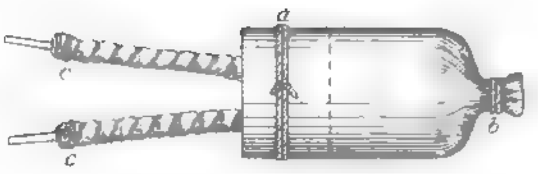


Fig.6.



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the efficiency of the fuze. After the fuze has been formed so far as described, the next operation is to insert the chemical mixture *f*, which consists of equal parts of sulphuret of antimony and chlorate of potash. Pounded carbon was added to this mixture in the original fuze, with a view of introducing an element capable of conducting a testing electric current: this addition was found to produce a small amount of uncertainty in the ignition of the fuze, it sometimes, for example, formed too good a conductor, it has consequently been discontinued. Over the chemical mixture *f* is placed the priming *g*, consisting of fulminate of mercury, generally 1 gr., but this amount would be regulated by the nature of the explosive with which the fuze was to be used. The fulminate of mercury must be tightly and securely placed over the chemical mixture, within the copper tube, this is done by a plug pressed carefully into it. The whole is then completed by an envelope of gutta-percha, which is also moulded round the wires *a*, *a*.

Prussian fuze.

A very similar fuze to this, in fact almost identical and only differing in form, was formerly used by the Prussians for mining purposes; this is shown in *Plate* XXVII., *Fig.* 2. *g* is a small cylinder of hard wood, through which a conducting wire is drawn to the hollow space *h* in the centre; similar precautions, to those adopted in the Austrian fuze, are taken in making and gauging the break in the conducting wire and in filling in the composition, which is similar to that used by Baron Von Ebner. The opening is stopped with a cork, shown at *i* in sketch.

Of these two last forms the Austrian is decidedly the best, being more carefully and scientifically made and less likely to be damaged by an accidental strain or tug, which might easily alter the interval between the points of the conducting wires, in contact with the fuze composition, in the Prussian fuze. The Prussians have abandoned this form and, it is understood, now use Abel's electric fuze in all cases, for land as well as submarine mining service.

Abel's mining fuze.

Another similar form of fuze is that invented by Mr. Abel, Chemist to the War Department. This fuze was devised, and experimented with extensively, in 1858, and the above more recently designed fuzes, (viz., Beardslee's, the Austrian and Prussian), are based upon the principles first applied in that fuze. It has been modified, since its first invention, in a few details; *Plate* XXVI., *Fig.* 1, shows its most recent form. The priming of the original fuzes consisted of 10 parts of subphosphide of copper, prepared by a special method, 45 parts of subsulphide of copper, and 15 parts of chlorate of potassa; these proportions of the ingredients, are, however, now varied, so as to furnish fuzes of different degrees of conductivity and sensitiveness, to suit different purposes. The ingredients are reduced to a very fine state of division, and are thoroughly incorporated in a mortar,

with the addition of a little alcohol; the mixture is then dried at a low temperature, and preserved in tightly stoppered bottles till required for use. This composition is very sensitive as an electric priming material, and is perfectly stable, so long as it is preserved from access of moisture. This condition, essential to the permanent efficiency of the fuze, is secured by the present form of construction, and the precautions adopted in packing such war-like stores as friction tubes, time fuzes, &c., suffice to ensure the preservation of these fuzes.

Construction of fuze.

In applying the electric spark to the explosion of fuzes, the distance from each other of the metallic points, between which the spark passes, must be adjusted with great nicety, and it is also important, when a number of charges are to be exploded in *divided circuit* by means of a magneto-electric machine, that no residue should be left between the poles after the explosion of the fuze, which would still serve to conduct the spark across the interval. The composition discovered by Mr. Abel, completely fulfils the latter condition, and the former is ingeniously secured by the form of fuze adopted and hereafter described, which is now an article of store, obtainable at the Royal Arsenal, Woolwich.

Referring to *Plate* XXVI., *Fig.* 1, *b*, *b*, is a body of beech wood, hollowed for half its length, for the reception of the priming charge, and perforated by three holes, one vertical for the reception of the capsule of sensitive mixture, and two horizontal to receive the conducting wires: *a*, *a* are two insulated copper wires introduced into the vertical perforation in the body and resting on the sensitive mixture: *d* is a small charge of mealed powder, contained in the cavity of the fuze, and fired by the ignition of the sensitive mixture.

The insulated wires are prepared for these fuzes in considerable lengths. They consist of copper wires of 24 gauge (=0·022 inch diameter), enclosed in a coating of gutta percha 0·13 inch in diameter, and separated about 0·06 inch from each other.

A piece of the double covered wire, about two inches long, is employed in the construction of the fuze. The gutta percha is perfectly removed from about 1·25 inches of each wire at one end, and the other extremities of the wires are furnished with clear sectional surfaces, by carefully cutting the double covered wire across with sharp scissors, care being taken that the ends of the wires are not pressed into actual contact by this operation.

A small quantity of the priming composition is put into a small cylindrical paper cap *c*, *c*, made to fit the double covered wire. The prepared piece of the latter is then inserted into this cap, and the exposed sectional surfaces of the wires are firmly pressed down upon the composition, so that the latter becomes compressed into close contact with them. The cap is afterwards coated with strong shellac varnish. The actual fuze is thus completed, but it has still to be fitted in such a manner as to permit of its ready

employment, and to protect it thoroughly from damp.

With this view the capped end of the double covered wire is inserted into the perforation *i* in the head of the wooden cylinder, so as to project about 0·15 inch into the cavity *d* of the cylinder. The bare ends of the wires are pressed into small grooves in the head of the cylinder *e*, *e*, and each extremity is bent into one of the small channels or eyes *d'*, *d'*, with which the cylinder is provided, and which are at right angles to the central perforation. They are then wedged tightly into position in these channels by inserting into the latter two small copper tubes (shown in outline *d'*, *d'*), which fit closely into the holes, and are driven in *over* the wire ends, being afterwards filed down flush with the surface of the cylinder.

The cavity of the latter is then filled with mealed powder, which is tightly rammed down, so that the fuze itself becomes firmly embedded in it. The opening of the cavity is afterwards closed by pressing into it a plug of softened gutta percha, and, finally, the completed fuze is coated with black varnish.

In order to connect this fuze with the electric exploding apparatus, it is only necessary to insert the bared extremity of each conducting wire into one of the small copper tubes or eyes *d'*, *d'* in the head of the fuze, and to fix it there by bending the wire round on to the wood, as shown at *e'*. Rigidity is imparted to the connection by twisting or turning the wires together over the top of the fuze, as at *f*. Perfect contact was formerly secured by a copper tack used as a wedge. In the fuzes now made, the size of the eyes has been reduced, so as to render this precaution unnecessary.

Before inserting the wires, with the fuze fixed upon them, into a charge of gunpowder or other explosive, it is advisable to cover the connections of the wires and fuze, either by wrapping a piece of gutskin, oiled canvas, or other waterproof material, round the head of the fuze.

The powder for ordinary fuzes is contained in the cavity of the wooden body, and the fulminate for detonating fuzes in a conical cylinder of sheet tin, tightly fitting on the fuze-head. It is of the form shown in *Plate* XXVI., *Fig.* 2 : the cone is of such size and form as to fit tightly into the hole, left for its reception, in the small priming discs of compressed gun-cotton.

Abel's fuze adapted for currents of high tension.

This fuze is adapted to the electricity obtained by friction, or to the momentary induced currents, derived from permanent or electro-magnets, or an induction coil. It can also be ignited by the direct voltaic current; about 60 cells of Daniell's or 30 cells of Grove's battery, being necessary to overcome the resistance with certainty, although very delicate fuzes may be fired by 12 cells of Daniell's battery or even less.

Testing Abel's fuzes.

Abel's fuzes can be tested by passing a weak current of three or four Daniell's cells through them, with an astatic galvanometer

in circuit. Each fuze should be thus tested before it is placed in a charge.

Abel's detonating fuzes. The difference between the detonating and the ordinary service electric fuze, consists only in the substitution of fulminate of mercury for the priming charge of gunpowder, and in the addition of an external, conical, tin casing to the bottom of the fuze. The heads of both forms of fuze are now painted black, but the conical projection of the detonating fuze is sufficient to identify it.

Effect of test currents on Abel's fuzes. Considerable doubts having been expressed as to the durability of the composition in this fuze, when subjected to the passage of test currents, some experiments were made at Chatham with a number of them, taken at random from our stock, with a view to test their efficiency in this respect, with the result shown in the following table, *p.* 103. These fuzes were of the old form, possessing a very high electrical resistance.

From these experiments it appears, that the electrical resistances of the fuzes were not materially altered by the passage of a test current through them, under any of the different circumstances in which it was applied; they all fired at the end of the experiments without any failure, and there seems to be no danger of ignition when using a test current, provided that current is properly adapted for the purpose. A large number of these fuzes are used in the course of instruction given in the Electrical School at Chatham, and the percentage defective is so extremely small, that it may be safely asserted that Abel's fuze is remarkably well suited for the purpose for which it was designed. It possesses the essential quality of certainty of ignition, and is further of such construction that its electrical condition can be easily and safely ascertained at any time, both before and after it is placed in the charge, by means of a test battery and delicate galvanometer.

Precautions necessary in testing Abel's fuzes of newest form. Some of the fuzes most recently made by Mr. Abel are extremely sensitive, and have been fired by the passage of a continuous current, of 6 Daniell's cells of the ordinary form, in from 4 to 6 hours and upwards. These very sensitive fuzes are no doubt preferable for simple mining purposes, but it must be borne in mind that they are unsuitable, and even absolutely very dangerous, when placed in a circuit in which they are subjected to the continuous passage of even a very feeble current of electricity, for a comparatively short time. When such a combination is required the less sensitive form of Abel's fuze, that with which our experiments were made, or that known as Abel's submarine electric fuze, must be used, and in fact may be used with perfect safety. It must not however be supposed that these very delicate fuzes, above referred to, cannot be tested; this may be done with perfect safety provided a suitable battery and galvanometer is used. It would not do however to put them in the hands of every one, and they should only be entrusted, when

Experiments to determine the effect of a voltaic current, from a few cells of a Daniell's Battery, passing through an Abel's Fuze, continuously and at intervals. Tested from time to time with a Reflecting Galvanometer.

Nature of Current applied.		Date.	Deflec-tion.	Date.	Deflec-tion.	Date	Deflec-tion.	Date	Deflec-tion.	Date	Deflec-tion.	Date	Deflec-tion.
		1866	Divi-sions	1867	Divi-sions	1867	Divi-sions	1867	Divi-sions	1867	Divi-sions	1867	Divi-sions
No. 1 Fuze	2 cells, continuous current.	28 Dec	10	7 Jan.	10	21 Jan.	10	4 Feb.	10	9 Feb.	10	8 Mar.	5
No. 2 „		„	45	„	30	„	30	„	70	„	30	„	20
No. 3 „		„	40	„	20	„	50	„	20	„	25	„	30
No. 1 Fuze	Tested once per day with 2 cells.	„	80	„	25	„	35	„	10	„	8	„	10
No. 2 „		„	30	„	25	„	10	„	7	„	10	„	20
No. 3 „		„	15	„	20	„	20	„	8	„	10	„	10
No. 1 Fuze	Tested at intervals with 2 cells.	„	30	„	10	„	10	„	10	„	10	„	8
No. 2 „		„	10	„	10	„	10	„	10	„	10	„	8
No. 3 „		„	50	„	60	„	20	„	20	„	15	„	15

The differences in the deflections, which in Thompson's Reflecting Galvanometer would be due to small differences of passing current, and may have been produced by slight differences of potential in the testing battery on the several occasions when it was used, or by an alteration in the conductivity of the fuzes. If due to the latter, it was proved by subsequent experience, that it did not in any way effect the efficiency of the fuzes, as they were all fired at the termination of the experiments.

used for submarine mining purposes, to a most careful workman, who must also be an experienced electrician. In using Abel's or indeed any fuzes, each should be carefully tested and marked, previous to being placed in the charge, to avoid the smallest chance of ignition in the latter position while testing.

Abel's electric fuzes for submarine service.

It is essential that any electric fuze, used for submarine mining service, should be capable of being tested with safety at intervals after it has been put in the charge and submerged in position, in order to ascertain that it is in good order and ready to act with certainty in exploding the mine, directly the electrical current is passed through it. To test Abel's ordinary electric fuze is, as already described, a delicate operation, requiring considerable care and skill. This fact has induced Mr. Abel to devise an electric fuze, specially suited for submarine mining operations and which can be tested with greater safety than that originally introduced by him: with this object in view, he has produced a fuze, which has now been constantly under trial, in a system of submarine mines, which has been, for a considerable time, under experiment at the Nore. The charges, &c. are connected up in precisely the same manner in which they would be used on service, and this fuze has been used with them, for more than 12 months, with very excellent results: it may therefore be pronounced a success. It differs from Abel's ordinary mining fuze only in the form of the bridge, which consists of a very intimate mixture of graphite and fulminate of mercury. This mixture is compressed into a cavity, into which the fuze terminals slightly project. The electrical conducting power of the mixture is regulated, by ramming it as tightly as possible till it offers the particular resistance desired: the attainment of this object is determined, by keeping a feeble current circulating through the fuze, with a galvanometer in circuit, during the ramming process. The priming, mealed powder for ordinary and fulminate of mercury for the detonating fuze, is attached, in precisely the same manner as in the ordinary Abel's mining fuze: the powder in the cavity of the wooden fuze head, and the fulminate in the long, conical tin projection, as already described. These fuzes may be fired through an electric cable, with a very much greater defect in it, than Abel's original form of mining fuze. In the Woolwich Vocabulary the several fuzes used for service are described as follows:—

No. 1. Fuze, electric, Abel. (The old service fuze). Colour of fuze head, black.

No. 2. Fuze, electric, Abel, submarine. (Used only for experimental and instructional purposes). Colour of fuze head, black.

No. 3. Fuze, electric, platinum wire. (Used only for experimental and instructional purposes). Colour of fuze head, white.

No. 4. Tube, electric, Abel. (The service electric gun tube). Colour of fuze head, black.

No. 5. Detonator, electric, Abel. (Similar to No. 1, but with fulminate of mercury priming). Colour of fuze head, black.

No. 6. Detonator, electric, Abel, submarine. (Similar to No. 2, but with fulminate of mercury priming). Colour of fuze head, black.

No. 7. Detonator, electric, platinum wire. (Similar to No. 3, but with fulminate of mercury priming). Colour of fuze head, white.

No. 8. Detonator for Bickford. (Specially designed for use with Bickford's fuze, to be fired thereby, and not by electricity). This differs entirely from all the electric forms of fuze.

Electrical resistance of fuzes.

The electrical resistance of the several forms of fuzes, designed to be fired by the passage of an electrical current, is a matter of great importance, and must be considered in connection with the circuits of the various combinations into which these fuzes enter. The resistances of the several forms of electric fuze, used for land or submarine mining, are as follows :—

The platinum wire fuze, Nos. 3 and 7 of official list, has a resistance of about $\frac{2}{10}$ of an Ohm, when cool, rising to $\frac{8}{10}$ of an Ohm at the moment of fusion of the platinum wire bridge.

Abel's mining fuze, Nos. 1 and 5 of official list, has generally an electrical resistance of from 1500 to 2000 Ohms, frequently rising, however, to a very much higher value. No precautions have been adopted in the manufacture of these fuzes, to secure uniformity of electrical resistance.

Abel's fuze for submarine service, Nos. 2 and 6 of official list, has an electrical resistance of from 3000 to 15000 Ohms.

In manufacturing electric fuzes, especially when they are required for submarine work, considerable care is taken to produce them of uniform electrical resistance. The necessity for this uniform resistance will be evident, when the various combinations into which these fuzes enter are described in detail. In the case of Abel's submarine fuze, this uniformity is secured by an electrical test, applied during the manufacturing process.

Extemporized fuzes.

In certain cases when Abel's or any other manufactured fuzes may not be obtainable, it may become necessary to make extemporary fuzes for use on the spot. This may be done in several ways, which have proved more or less successful.

For example, a fuze, capable of being used with a voltaic battery of a large number of cells, may be extemporized on the principle of Beardslee's, as described in the *Report of the Floating Obstruction Committee*, as follows :—

"A small cylinder, *Plate* XXVII., *Fig* 3, of hard wood or cork, about $\frac{5}{8}$ inches in diameter and $\frac{3}{8}$ inches thick, is provided with a groove *a* round its circumference, and two perforations *b*, *b* about $\frac{1}{4}$ inch apart, of a suitable size to receive two moderately thin pieces of copper wire, (about 18 B W gauge being a convenient size). One extremity of both of these wires is sharpened with

a file and then converted into a hook, the head of which is afterwards flattened, as shown in *Plate* XXVII., *Fig.* 4.

"The straight ends of the wires are then passed through the holes in the cylinder and the flattened heads are fixed in the wood, by driving the pointed extremities into the latter. In this way the broad thin metal surfaces, which form the poles of the fuze, are fixed in a parallel position on the surface of the wood or cork, and should be as close together as possible, without actually touching. This arrangement is shown in *Plate*XXVII., *Fig.* 5. Before, however, the wires are thus placed in position, the surface of the cylinder, upon which the poles are fixed, is brushed over lightly with a feather tip or hair pencil, which has been dipped into a solution of ordinary photographic collodion. When the poles have been fixed into the cylinder thus prepared, the small surface of wood which intervenes between them is coated with graphite, by drawing a pointed blacklead pencil across it two or three times. A cap of thin paper is then tied round the cylinder *a*, *Fig.* 6, so as to enclose the poles of the fuze; this cylinder is filled compactly with fine grain gunpowder and the open end is then choked, as shown at *b*, *Fig.* 6."

"The protruding wires of the fuze, *c*, *c*, *Fig.* 6, which serve to connect it with the conducting wires, are coated, to within a short distance of their extremities, by moulding ordinary beeswax round them with the fingers, and then tightly wrapping the wax over with thin strips of tape or rag of any kind, which is secured at the ends with thread. The entire fuze, except the bare ends of the wires, may then be brushed over with Brunswick black, or any other description of varnish or lacquer which may be at hand."

"The only material, not universally obtainable, which is required in the production of these fuzes, is collodion, which is, however, now so very extensively used, that it will generally be readily procurable. A small bottle, corked or stopped, containing one or two ounces of collodion, will suffice for the preparation of a very large number of fuzes."

This fuze may be fired by means of a voltaic battery of sufficient power or by Wheatstone's magnetic exploder, the former of which generates a continuous current and the latter a rapid succession of short currents. It would rarely be fired by means of a frictional or other machine capable of producing a single discharge only, because, in order to produce the necessary heating power, a continuous passage of the current, through the plumbago bridge, is essential. In using this fuze, it frequently happens that a short interval elapses between the closing of the electrical circuit and ignition, this time being required to produce the necessary amount of heat alluded to.

Fisher's extemporized fuze.

Another form of fuze, designed by Commander Fisher, R.N., in conjunction with Mr. May, Gunner R.N., of H.M. Ship "Excellent,"

is similar in general construction to the above but differs in the composition of the bridge. For plumbago Comdr. Fisher substitutes a mixture of powdered charcoal and resin; this, he states, produces a fuze which tests sufficiently well and is very certain of ignition. The materials of which it is composed are so simple and easily procured, that it bids fair to become a very useful fuze, easily made where a supply of the more perfect Abel's fuzes may not be at hand. A detailed description of the construction of this fuze, may be found in a confidential book entitled, *A Treatise on Electricity, and the Construction and Management of Electrical and Mechanical Torpedoes*, 2nd Ed., by Commander J. A. Fisher, Royal Navy. As, however, the efficiency of a mine depends very considerably on the quality of the fuze, extemporary fuzes should never be used when the more perfect forms are attainable.

Position of fuze in a charge.

Next, as regards the position in which the fuze may be most advantageously placed, and the number required to fire any given charge.

It has been already stated that, in order to develop the full explosive effect of even a small charge of *powder*, when fired under water, a very strong case is required, in fact that the maximum effect of a 4lb. charge was not attained, until a case of ⅜″ iron, capable of standing a gradual pressure from within of 330lbs. per square inch, was used. For large charges, of 500lbs. and upwards, it is therefore evident, that it would be quite impossible to make cases proportionately strong to secure a similar development of explosive effect, because they would become enormously heavy.

We may, however, to a certain extent obviate this effect of loss of power, as it were, by igniting the charge, when of large size, at several points, providing in fact several centres of ignition, and thus burning as much as possible of the charge and converting it into gas, before the envelope is broken and the water admitted.

Maximum charge to be fired with a single fuze.

Let us first consider what would be the maximum charge which it would be desirable to fire with a single fuze, supposing that in other respects, it is favourably circumstanced, that is to say the case being of the best form and of as great strength as circumstances will admit, &c. The radius of ignition due to a single fuze, when fired under the circumstances above described, has not yet been ascertained, but it is supposed to be about 1ft., and starting with this basis, our maximum charge, to be fired from a single centre of ignition, is at once determined at about 250lbs. If therefore this supposition be correct, and we may assume that it is till reliable data have been obtained, we must use a single centre of ignition for all charges of less than 250lbs., of powder, adding a fresh fuze, suitably placed, for each additional 250lbs. or fraction of 250lbs. in the charge to be fired.

This has reference to gunpowder, fired with an ordinary fuze.

When gun-cotton and a detonating fuze is used, a much greater bulk may be exploded from a single centre of ignition.

Distribution of several fuzes in a large charge.

The distribution and holding in a proper relative position of a number of fuzes in a large charge of powder, is a matter of some little nicety, and in addition we have the increased difficulty of testing the fuzes after being placed in the charge, and the increased chance of failure and trouble in replacing a defective fuze, or adjusting any accidental derangement of the conducting wires, should a defect occur in the heart of the charge itself, which would render the emptying out of the case necessary. In order to obviate these defects, the following very ingenious arrangement has been suggested by Captain Harding Steward, R.E. The description is extracted from his report:—

Captain Steward's tube.

"The charge of powder should be packed in an india-rubber bag, about 12 inches in diameter (internal) and of a length sufficient to contain it, (a bag 42 inches long will take a charge of 150lbs.)"

"For the firing arrangement a brass tube and a fuze primed with powder is requisite. The brass tube should be sufficiently long to run the whole length of the bag, when filled and tied at the end, and should have an internal diameter of one inch. To fit the tube for its object, it is necessary to cut slits $\frac{1}{2}$ inch wide and $1\frac{1}{2}$ inches long, at central intervals of 3 inches and following a spiral line round the tube, *Plate* XXVIII. These slits should be covered with brass wire gauze of a mesh sufficiently small to exclude powder, and one end of the tube should be closed and the other provided with short lugs."

"A fuze primed with 2 drachms of powder, placed in the end of the tube and well secured to the lugs, also tightly covered so that only the wires protrude, completes the arrangement. It is then put altogether in the central line of the charge and secured so that it shall not vary its position."

"On applying electricity of a kind suited to the fuze employed, jets of gas are driven from all the openings in the tube. These jets, accompanied by flame or without it, fire the powder within their reach and the result is the complete ignition of the outlying portions even before the gas evolved by the grains first ignited, has time to rupture the case or bag and let in the water."

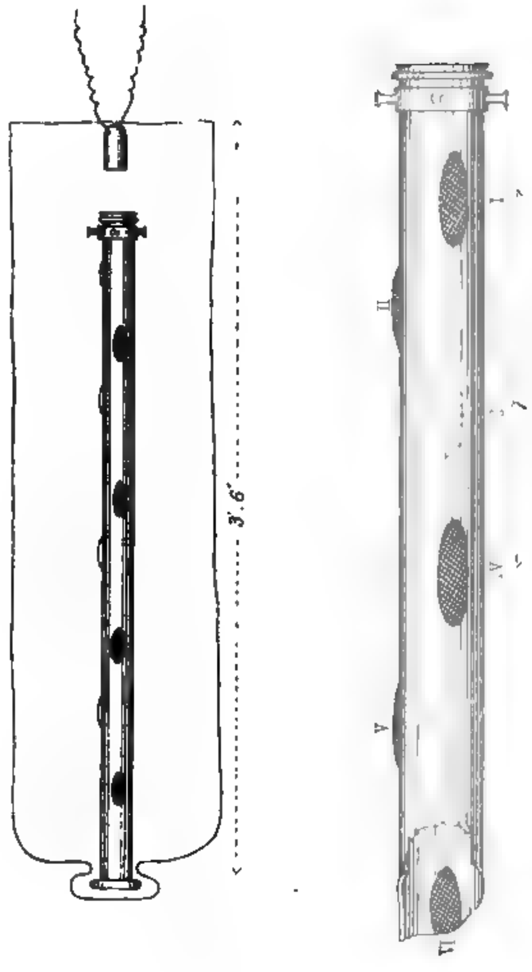
"The experiments made with this mode of ignition have, owing to circumstances, been confined to lighting several trains and heaps of powder arranged about the tube, at intervals sufficiently large to prevent them communicating on one being fired. The ignition was in all cases attended with perfect success."

Fuze.

"The fuzes employed were of my own making and suited for the electricity of a magnetic exploder. Equally good results can be obtained by priming Abel's mining fuze or his experimental fuze, with two drachms of powder, provided that the fuze, when packed, fits the tube tolerably well. Two drachms of powder

PLATE XXVIII.

STEWARD'S FIRING TUBE,
FOR SUBMARINE MINES.



Lithographed at the S. M. E. Chatham

only are proposed, as with three and with four drachms, it was found (in the above experiments), that the blast not only drove away the powder, but prevented the emission of gas from the two or three holes nearest to the fuze. It is, however, possible that with a confined charge an increase of the priming might not be attended with the above results. If it is thought desirable to employ two fuzes, so that, in the event of one of them proving to be bad, ignition may be secured through the other, the same can be done by arranging two tubes three inches apart, connecting their ends in order to keep them in their relative positions."

"The mode of ignition proposed will be found so complete, that metal cases for torpedoes can be dispensed with and barrels used instead: for a water-tight covering is all that is required for the charge."*

"The proposed plan is also likely to prove useful in all cases in which ignition, by means of chemical fuzes, or by detonation, is used; for the powder, according to existing plans, is only ignited at a single point, and that one is close to the exterior of the mass of the charge; consequently, the combustion of the charge would take place under unfavourable circumstances."

"In the event of the proposed mode of ignition being employed for land mines, it will certainly economize powder, but its utility will not be so apparent, for the surrounding earth cannot spoil a portion of the charge as water does; also that defective ignition can always be compensated for by an increase of the charge. The plan, however, permits of the series of fuzes being dispensed with, which is, however, a mode of ignition little used in field mining operations."

"With very large charges (say from 300 to 500lbs.), the following out of the cylindrical form, with a diameter not exceeding 12 inches, as recommended, would involve inconveniently long powder cases. It is therefore necessary to subdivide the mass of powder, and to employ branches with the tube. This can be best effected by treating a mass of powder, as made up of a series of cylinders 12 inches in diameter, and providing a tube for each, one case alone being provided for the whole."

Tube with branches.

Such a tube, with branches radiating from a single point, has been devised by Captain Steward. In the head of each branch he places a small priming charge, and the gas produced by its ignition would no doubt act in a similar way, down each branch, to that of the fuze with the single tube.

The advantages of a single fuze, or centre of ignition, in each charge are very great. It is extremely difficult to test a number of fuzes of high electrical resistance in a single circuit, without a very delicate galvanometer, or such an increase of power in the

* It is impossible to say whether this assertion is strictly borne out by facts, the experiments with Steward's tube having only been tried with very small charges.

testing battery as to run the chance of firing one of the fuzes, and thus causing a premature explosion. Again, one bad fuze among a number combined for the ignition of a large charge, might destroy the efficiency of the whole arrangement or cause difficulties in ignition. And finally, should the tests indicate something wrong, it would be a comparatively easy matter to replace a single defective fuze at one centre of ignition, whereas the re-adjustment of a number would involve considerable difficulty, and probably necessitate the emptying out of the entire case.

A few experiments on a very small scale, with charges of 6lbs. of powder, were tried by the Floating Obstruction Committee, to ascertain the value of the tube, but no definite results were obtained, nor is it likely that they would be with such small charges, supposing that the theory, that a charge of 250lbs. of powder may be fired with a single centre of ignition, is correct; in order to settle this question it would be necessary to try comparative experiments with charges of not less than 500lbs. of powder, the comparative effects with and without the tube being carefully measured by any suitable means.

Though, for the present, we are not quite prepared to concur in Captain Steward's ideas, that indian-rubber bags, combined with tubes, but without a metal covering of such strength as to develop the explosive force, are sufficient practically to secure the complete ignition of a charge; or that a considerably elongated cylinder is the best form of case; still the tube arrangement is extremely ingenious, and would probably render the use of a large number of fuzes, in a charge of powder of considerable bulk, unnecessary. The adoption of gun-cotton, fired with a detonating fuze, as our explosive agent for submarine mines, having in a great measure solved the question as regards the form and strength of case to be employed, more extended experiments with the tube have not been carried out.

Austrian plan of surrounding fuze with gun-cotton.

Several other methods have been suggested for producing this very desirable result of a thorough ignition of the charge, for instance, the Austrians place a pound or two of gun-cotton in actual contact with the fuze, and this substance being much quicker of ignition than gunpowder, the gas and flame produced is supposed to permeate the interstices between the grains of the latter and thus secure a thorough combustion of the charge.

Gun-cotton bag suggested by Lieutenant Chadwick, R.E.

Lieut. Chadwick, R.E., has suggested enveloping the charge of powder in a bag of gun-cotton, under the supposition that, by surrounding it, as it were, by an envelope of flame, which would be produced by the more rapid ignition of the gun-cotton, the combustion would be continued inwards and that none of the powder could escape unburnt. The effect of such an arrangement would be well worth trying.

Use two

In order to prevent any chance of a miss fire, the Austrians

recommend the use of two fuzes at each centre of ignition, so that if one fails there is a chance for the other to produce the required result, and there is no doubt that, in all cases, especially where there is any question as to the good quality of the fuzes, this is a very necessary precaution, especially when there is only one centre of ignition in a charge. It must not however be confounded with the use of two fuzes, one at each of two distinct centres of ignition, in a charge, it is simply the arrangement of two fuzes at a single point, where one if good would do the work, and is only a matter of precaution. In carrying out the details of our own system of submarine mines, two fuzes are always used at each centre of ignition. *fuzes at each centre of ignition.*

When no arrangement, such as Steward's tube, is used, and we wish to distribute a number of fuzes about in the mass of any given charge, a very good means of keeping them in their proper position is to lash them to pieces of wood which, being rigid, may be arranged so as to remain stationary. This should be done before the charge of powder or other explosive is put in the case. *Fixing fuzes in position.*

With reference to the above remarks, on the subject of the number of fuzes required and their distribution in a given charge of large size, it must always be borne in mind that, when gunpowder or gun-cotton fired with an ordinary fuze is used, a case of sufficient strength to develop the force of the charge is always necessary, whatever number of points of ignition may be employed. In fact it cannot be too strongly impressed that the provision of a strong case, (except where gun-cotton, fired with a detonating fuze, or some compound similar in the character of its ignition, is used), is a matter of vital importance. *A strong case required for gunpowder fired with ordinary fuze.*

After numerous experiments, carried on by the several committees, which have had this subject under consideration, it has been decided to adopt gun-cotton—fired with a detonating fuze—as the explosive for the service of submarine mines. This decision, which is based upon thoroughly sound principles, enables us to get over many of the difficulties inseparable from this question: one centre of ignition only is required for a charge even of the largest size, and cases of much thinner metal may be used without any loss of working power. Gun-cotton may not always be procurable, and it has been thought necessary to record many of the foregoing remarks in view of the probable use of gunpowder for this service. Should gunpowder be, of necessity, employed, it should always be fired—when possible—with a detonating fuze. *Gun-cotton approved for submarine mining service.*

CHAPTER VI.

Electric Cables.

The next point to be considered is the most suitable form of insulated conducting wire, or cable, for employment with electrical submarine mines.

Qualifications of electric cables.

The qualifications required in such a conductor are as follows:

1st.—Capacity to bear a certain amount of strain without breaking, and without damage to the insulation.

2nd.—Good insulation, composed of such a substance that it may be readily stored and kept for a considerable time without being injured. This is an essential, as the lines will only be submerged while actually in use in time of war, for which purpose they must consequently be kept in store, and always ready, in sufficient quantities.

3rd.—For situations where there is a rocky or shingly bottom they must be provided with an external covering capable of protecting the insulation from destruction. Special precautions must, of course, be taken to secure the cables at points where they may be necessarily exposed to a considerable wash of the sea, such as the places where they may be led into a fort, &c.; but as there are others where no such special precautions can be applied, we must provide for the contingency by an external protecting covering over the insulation.

4th.—Pliability, so that it may be wound on or payed out from a moderately sized drum without injury.

Austrian cables for submarine mines.

Several forms of cable have been devised to meet the above conditions. That used by the Austrians was manufactured by Messrs. Siemens, Brothers, of Charlton, and consists of a metallic conducting wire, insulated with gutta-percha, and protected externally by hemp and by several plies of copper tape, wound on in a peculiar manner, so that each strip overlaps the preceding one, as shown in *Plate* XXIX, *Fig.* 1; this is a patent of the above-mentioned firm.

One defect of gutta-percha insulation is its liability to become hard and brittle, when exposed to dry heat, and the consequent necessity of keeping it stored under water. In order to obviate

PLATE XXIX.

SUBMARINE ELECTRIC CABLES.

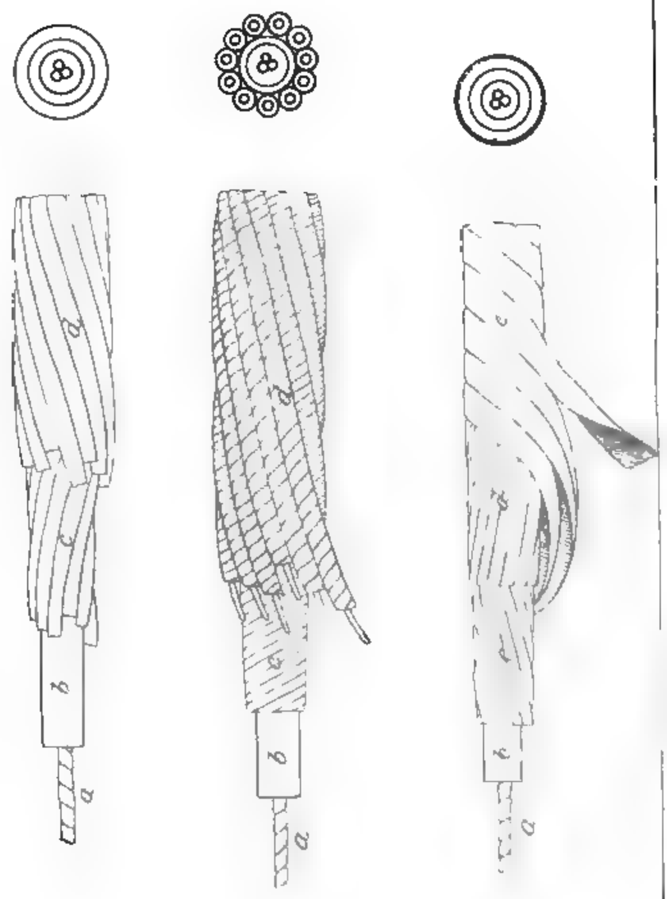


Fig.3 Fig.2. Fig.1.

Lithographed at the S M E Chatham. B Butler Corpl R E

this defect, Messrs. Siemens have recently replaced the gutta percha by vulcanized indian-rubber in some of their cables.

The following list gives the dimensions and composition of some of the forms of cable, manufactured by them for military purposes:—

No. of cable.	Price per statute mile, free on board, in London, including packing.	Total weight per statute mile.	Description.
	£ s. d.	cwt.	
3006	85 0 0	6	A conductor, consisting of a strand of 3 soft iron wires, each of 0·05 inch diameter, insulated with 2 layers of gutta percha and compound to 0·236 inch, served with best Italian hemp strings, and covered with one continuous copper sheathing to a total diameter of 0·39 inch.
3029	81 0 0	4¼	A conductor, strand of 3 soft iron wires, each 0·03 inch, covered with 3 layers of vulcanized indian-rubber to 0·264 inch, a layer of hemp, sheathed with copper sheet, and covered with tape painted white.
3030	81 0 0	4¼	Same as last, but covered with plaited hemp instead of painted tape.
3031	70 0 0	4¼	Same as 3029, but no outer covering of tape or hemp on the copper.
5014	63 0 0	2¼	Same conductor as 3029, served with hemp, and covered with tape painted white, with no copper sheathing.
5015	63 0 0	2¼	Same as last, but covered with plaited hemp instead of painted tape.

Advantages and defects of cables protected with copper tape.

We have occasionally found the copper tape covering on these cables to act prejudicially under certain circumstances; as for example, if by any chance a kink occurs in paying out the line, and a sharp strain is suddenly applied, the copper tape may at that point be drawn in such a way as to cut through and destroy the insulation. In handling these cables, therefore, it is necessary to be extremely careful. When once laid down, the outer covering of copper tape appears to be a very efficient protection, and it is of course less affected by the sea water than iron. In using it,

however, it is necessary to take certain precautions to obviate the electrical action which would ensue, were the copper covering to be brought into contact with iron in salt water. Under such conditions, the iron would inevitably corrode very rapidly. The rapidity with which the electrical action destroys iron, under the above circumstances, is almost inconceivable, and much trouble on this account has been experienced in carrying on some of our experiments. A considerable quantity of electric cable of this form, was used by the Austrians during the war of 1866, as well as by the Germans during the war of 1870-71, in connection with the defence of their ports by submarine mines; on both occasions it was found to be reliable and efficient.

An elevation and section, showing the general construction of Messrs. Siemens' cables is given in *Plate* XXIX., *Fig.* 1; *a* is the conductor, *b* the insulation of gutta percha or indian-rubber, *c* and *d* two coverings of hemp and *e* the outer protecting copper sheathing, laid on in a peculiar way.

Hooper's cable.

Another form of electric cable, suitable for submarine mining purposes, is manufactured by Hooper's Cable Company, and possesses many qualities which render it especially applicable for this service. It may be described as follows :—

A metal strand conducting wire, generally of copper, covered with an alloy, to protect it from chemical action; over this is a thin coating of raw indian-rubber, then a thin coating, called the separator, of indian-rubber mixed with oxide of zinc; over this is a thickness of vulcanized indian-rubber, more or less, according to the amount of insulation required; next to this comes a layer of indian-rubber felt, and the outside is protected by tarred hemp and iron wire, or, where the cable is not to be subjected to such usage as to render an outer wire covering necessary, by a simple layer of indian rubber felt. In the process of manufacture, the indian-rubber, after being laid on, is subjected to a very high temperature, under a pressure of steam at 300 degrees Fahrenheit, which fuses it into a solid mass; and while thus improving the insulation, renders it indestructible by heat of any degree likely to occur even in a tropical climate.

The object of the separator is to prevent the sulphur of the outer or main insulator penetrating to, and attacking, the metal conductor.

The high degree of insulation attained is due to the use of indian-rubber, which is an excellent di-electric, and its capability, in resisting high temperatures, has been very severely tested, in existing lines of telegraph in Ceylon, India, and the Persian Gulf, most favourable reports of which are said to have been received. The advantages claimed for his cable by Mr. Hooper are summed up briefly as follows: high insulation, flexibility, and capability of withstanding dry atmospheric heat, which would destroy gutta percha.

An elevation and section, showing the general construction of Hooper's cables is given in *Plate* XXIX., *Fig.* 2 :—*a* is the conductor, *b* the indian-rubber insulation, *c* the covering of tarred hemp, and *d* an outer covering of iron wires, No. 11 B.W.G. each separately covered with tarred hemp, wound on spirally.

The table in page 116 gives in a comprehensive form, the different cables of Hooper's form suitable for submarine mining purposes. Those with a strand conductor of three or four small wires only, viz. Nos. 323A, 321A, 376 and 323, do not possess a very large amount of tensile strength, which, being necessary for submarine mining purposes, must be supplied by the addition of an outer covering as already described.

Defect of Indian rubber insulation

Indian-rubber insulation possesses one defect, as compared with gutta percha, viz., that it does not cling, as it were, to the metallic conductor; and that, consequently, if the indian-rubber is once cut through, any strain on the cable has a tendency to pull the conductor away and increase the fault. The conductor cannot be thus pulled away from the insulation when the latter is formed of gutta percha, which seems to cling to it and prevent such a result. As far as we yet know, however, indian-rubber is not so easily affected by dry heat as gutta percha, and is therefore preferable for storage, the latter cracks and perishes unless considerable care is exercised in preserving it, which is best done by keeping it under water. Indian-rubber possesses higher di-electric properties than gutta percha.

Advantages of Indian-rubber insulation.

Gray's cable

A cable, very similar in appearance and principles to Hooper's, is manufactured by the Indian Rubber, Gutta Percha, and Telegraph Works Company, of Silvertown, North Woolwich. It consists of a copper strand conductor, tinned, insulated with vulcanized indian-rubber, over which a felt tape covering is laid, subjected to heat at 300° F. under steam pressure and with an external protecting covering of hemp and iron wires. The chief difference in this cable, as compared with Hooper's, appears to be the absence of the separator, on the use of which Mr. Hooper lays peculiar stress, while Mr. Gray, on the contrary, does not believe in it, and relies entirely on the tinning to protect the copper conductor. The form of insulation, adopted by the Silvertown Company, is called Gray's patent.

Cable used in demolition of the wreck of "Golden Fleece."

A cable of this form was used in the operations against the wreck of the "Golden Fleece" at Cardiff, in December, 1869, and January, 1870.

It consisted of a strand of 3 No. 20, B.W.G. copper wires, insulated with indian rubber, (Gray's patent), to a diameter of $\frac{2}{10}$ inches, and protected externally with two servings of tarred hemp, wound on spirally in opposite directions. This cable possesses considerable tensile strength; when one end of a short length was made fast to a rigid point, it resisted two men, pulling at it with their full strength, without injury. It remained perfect

HOOPER'S PATENT INSULATED CABLES, SUITABLE FOR SUBMARINE MINES.

No. of specimen	Conductor.			Hooper's Patent Di-electric.		Resistance per knot temperature 75° Fah.		Gutta percha required for an equivalent induction, (inductive capacity), to Hooper's patent di-electric.	Outside diameter	Total weight per knot.
	Consisting of	Weight per knot.	Diameter.	Weight per knot.	Diameter,	Conductor B.A. Units.	Di-electric Millions B.A. units.	Diameter.		
		lbs.	inches.	lbs.	inches.				inches.	lbs.
383	7 No. 18s.	300	·147	300	·374	4·522	5,000	·472	·400	640
353	7 No. 22s.	109	·087	346	·380	12·007	9,200	·549	·400	501
370	7 No. 18s.	300	·147	248	·340	4·052	5,062	·419	·360	585
373	7 No. 20s.	180	·100	264	·340	7·052	6,000	·450	·360	481
375	7 NO. 22s.	109	·087	274	·340	12·007	6,949	·478	·360	420
372	7 No. 20s.	180	·110	200	·300	7·052	5,000	·385	·320	407
323A	3 No. 21s.	62	·064	160	·260	23·047	8,000	·369	·280	244
321A	3 No. 20s.	78	·070	132	·240	17·061	7,884	·326	·260	228‡
376	3 No. 21s.	62	·064	136	·240	23·047	7,890	·334	·260	216§
323	4 No. 22s.	62	·067	92	·200	23·047	4,000	·263	·220	169‖

‡ The multiple cable connecting Ireland and Scotland contains this as the centre core.
§ This cable was supplied for the Abyssinian Field Telegraph.
‖ These cores are extensively used in India, on the principal railway telegraphs, and in the Government offices.

during the whole of the operations against the wreck of the "Golden Fleece," which extended over a period of two months of very rough usage, and turned out to be admirably suited for the purpose to which it was applied. Its cost is about £35 per mile.

For rocky bottoms, or situations where the cable is subjected to risk of mechanical injury, a further external protection, of iron wires and tarred hemp, must be used. This would of course increase the cost.

A full size elevation and section of this cable, which give a very good general idea of the forms manufactured by the Silvertown Company, are shown in *Plate* XXIX., *Fig.* 3 :—*a* is the metallic conductor, *b* the insulating material, (Gray's patent), *c* and *d* two servings of tarred hemp, wound on spirally in opposite directions. When required, an outer protecting armouring of galvanized iron wires, each wire covered with tarred hemp, is laid on, in addition, with a long twist.

Forms of electric cables approved for service.

The forms of electric cable above described, as suitable for military service, are all patterns usually made for commercial purposes. After much consideration, and with the experience gained by a long series of experiments, made under the auspices of previous Committees as well as their own, the Torpedo Committee have decided to adopt electric cables of the following construction, as most suitable for the special requirements of submarine mining service: in this decision they have retained, to the utmost extent, the ordinary commercial patterns in general use, in order to simplify manufacture. A reserve, of the several approved forms of electric cables, has been provided to meet the contingency of a sudden outbreak of hostilities.

Construction of core.

The form of core adopted is the same for all classes of cables, whether single or multiple. It consists of a strand conductor of 4 No. 20 B. W. G. copper wires, tinned; the copper to be of quality equal to not less than 92 per cent of pure copper, possessing an electrical resistance of not more than 14 Ohms per nautical mile; insulated with vulcanized indian-rubber to a diameter of ·24 inches: over the di-electric a layer of felt is wound on and the whole subjected to a temperature of about 300° Fahrenheit, under steam pressure, to consolidate the insulation. The size of the conductor chosen, is regulated by the following conditions:—it is considered by the Committee to be the minimum applicable for use with the platinum wire fuze, which is to be employed under certain circumstances, and which involves the consideration of quantity currents and corresponding conductivity. The wires forming the conductor are tinned, to protect them from the action of the sulphur in the di-electric. In addition to the tinning, Mr. Hooper recommends what he terms a separator, as already described. Vulcanized indian-rubber was selected, in preference to gutta percha, because it is less liable to be injured by dry heat, and may consequently be stored dry with much less chance of

deterioration: as these cables may be required for use in a tropical climate, it is a decided advantage to be able to store them dry, not only in transit but on arrival at their destination. Dry heat and light have a very injurious effect upon gutta percha, causing it to become brittle and to crack when bent, after exposure to their influence for a comparatively short time. Cables insulated with gutta percha must therefore always be stored under water, for which purpose it would be necessary to provide suitable tanks. The service electric cable may be stored either dry or wet: it must be borne in mind, however, that it must be kept always dry or always wet, (under water), as any alternation of these conditions would tend to rot the hemp covering and di-electric. In addition to the qualifications enumerated, the service core is sufficiently pliable, as light as is consistent with the work to be performed, moderate in cost, and easily manufactured.

Storage of electric cables.

Single cored, armoured cable.

A single cored, armoured cable is provided for use, in a manner to be hereafter described, in connection with each mine of a group. It consists of the core above described, over which a covering of tanned, picked, Russian hemp is laid on spirally, to form a padding, followed by 10 No. 13 B.W.G. galvanized iron wires, each wire covered with tarred Russian hemp, wound on spirally, in an opposite direction to the hemp padding, with a twist of one revolution in about 13 inches. In order to prevent these protecting wires from gaping, when the cable is bent or kinked, a further covering, consisting of two servings of hemp, laid on spirally in opposite directions and passed through hot composition, is added: this composition consists of tar and pitch; so proportioned as not to be too soft when cool. The external diameter of this cable, complete, is about $\frac{7}{8}$ in.; its weight in air is $27\frac{59}{112}$ cwt, that in water being $14\frac{49}{112}$ cwt. per nautical mile, and it has a breaking strain of $62\frac{1}{2}$cwt. It has been found by experiment, that when an electric cable is broken by a strain, the protecting wires and conductor part simultaneously. Electric cables of this form have been made for the Government reserve of stores, by the Indian-Rubber, Gutta Percha, and Telegraph Works Company, of North Woolwich, by Henley, of North Woolwich, and by the Hooper's Telegraph Company, of Mitcham. The price at which it has recently been supplied by the latter is £74 per nautical mile.

Seven cored, multiple cable.

Multiple cables are provided for service, to be used under certain conditions which shall be hereafter described. The multiple cable, to connect the testing room with each of the junction boxes, from which the single cables to the several mines radiate, consists of 7 single cores, (each of the form already described), formed into a strand, over which a padding of hemp fibres is laid on longitudinally, followed by an armouring of 16 No. 9 B.W.G. galvanized iron wires, each wire covered with tarred tape, laid on spirally with a twist of one revolution in 15

inches: the whole finally covered with two layers of hemp and composition, laid on with a short twist in opposite directions. The external diameter of this cable is $1\frac{1}{4}$ inches; its weight in air is $78\frac{20}{112}$ cwt, and in water $45\frac{32}{112}$ cwt. per nautical mile; and its breaking strain is 135 cwt. A combination of seven cores is used, because that number forms a convenient and compact strand, one core in the centre and the other six round it, over which the armouring can be effectively laid on in an even uniform manner. The whole forms a cable which is not too bulky or heavy to handle, when proper appliances are used. The price at which this cable has been supplied is £357 per nautical mile.

Electric cable connecting circuit closer to mine.

The cable connecting the circuit closer to the charge is always subjected to exceptionally great wear and tear, it has been found necessary, therefore, to make special provision for the protection of this part of the electrical circuit. Experiments extending over many months have proved, that if subjected to that vibratory motion, which is produced by the waves of the sea, in ever so slight a degree, the wires forming the armouring of the ordinary, service, single core cable, break short off after a little time: this kind of motion is necessarily greatest between the circuit closer and the charge, even when the former is some feet below the surface of the water. To meet the difficulty, a special form of armouring, combining the greatest amount of strength and pliability, has been designed. These qualifications (lightness and pliability) are essential, the first to prevent an unnecessary weight being attached to the circuit closer and the second to obviate the effects of the rocking motion. The form of cable provided for this service consists of the approved service core, over which a padding of hemp is laid on as before; over this 9 strands, each of 14 No. 22 Bessemer steel wires, each strand covered with tarred hemp, are wound on with a twist of one revolution in $7\frac{1}{2}$ inches: over this are the usual external coverings of tarred hemp, wound on spirally in opposite directions. The weight of this cable in air is $52\frac{106}{112}$ cwt., and in water $28\frac{4}{112}$ cwt. per nautical mile; and its breaking strain is about 65 cwt. It was used during the whole winter of 1871-2 in connecting the circuit closers of the experimental system of mines at the Nore, and after six winter months severe trial appeared to be in as good working order as when first put in the water. The price at which this cable has been supplied is £127 per nautical mile.

Electric cables for telegraphic purposes.

Electrical communication must always be kept up between the several detached works of a maritime fortress: this is essential in all cases and absolutely indispensable when a system of submarine mines forms a part of the defence, as without it the system of firing mines at will, by cross bearings, cannot be employed. Experience has proved, that electrical lines of communication of this nature must be buried beneath the surface of the ground, to protect them from the enemy's fire. During the late siege of

Paris by the Germans, the air lines of electric telegraph, carried on poles and insulators in the usual way, were very soon destroyed by the enemy's shells, while the buried lines remained in good working order during the entire period of the siege. It is easily understood too, how a sudden break in a line of electric telegraph, producing an interruption of signalling at a critical moment, may be productive of the most serious consequences. Under these circumstances it has been decided to provide an electric cable for telegraphic service, in connection with our system of defence by submarine mines.

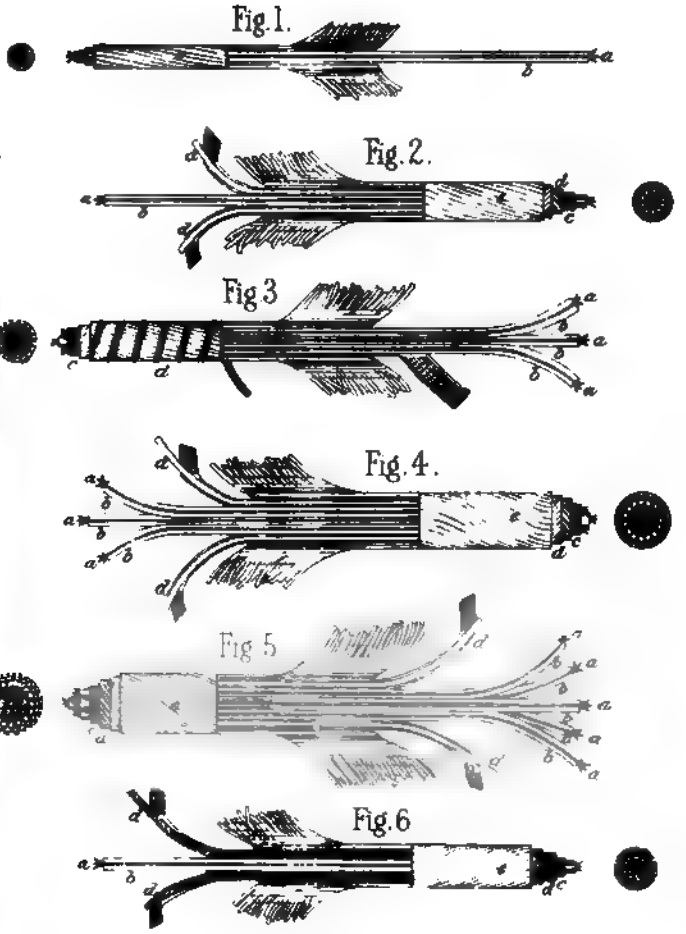
Single telegraph cable. For simple purposes of telegraphic communication, between one station and another, for land service, a cable has been designed, consisting of the service core, protected by an outer covering of tarred hemp laid on spirally. This cable may be laid on the ground, to form temporary connections, or it may be buried when the stations at its extremities are more permanent. The weight of this cable in air is $4\frac{13}{112}$ cwt., and in water $1\frac{36}{112}$ cwt. per nautical mile; its breaking strain is $7\frac{1}{2}$ cwt. The price at which this cable has been supplied is £33 10s. per nautical mile.

Single armoured telegraph cable. Where it is necessary to connect two forts or batteries separated by water, (an arm of the sea for instance), for telegraphic purposes, the single, armoured cable, described at page 118, may be employed.

Four cored unarmoured cable. In carrying out a system of defence by submarine mines, where firing by cross bearings is employed, a special electric cable, to connect the firing stations has been designed. As a general rule, mines to be fired by cross bearings would be arranged in three lines, converging on one of the stations, in a manner to be hereafter described. Each line of mines would be provided with a conducting wire, in connection with the firing arrangements, while one line of conducting wire would be required for telegraphic signalling. For the purpose in question, a four cored cable has consequently been provided. For land service this cable consists of a strand of four service cores, covered with a padding of hemp, over which two servings of tarred hemp, laid on spirally in opposite directions, are wound. This cable may be buried or laid on the ground, in the same manner as the single, unarmoured cable. Its weight in air is 16 cwt., and in water $4\frac{59}{112}$ cwt. per nautical mile; its breaking strain is $17\frac{1}{2}$ cwt. The price at which this cable has been supplied is £137 10s. per nautical mile.

Four cored armoured cable. Where the stations to be connected are separated by water, a four cored, armoured cable must be employed. For this purpose a cable has been provided, consisting of a strand of four of the service cores, covered with a padding of hemp, over which an armouring of 15 No. 13 galvanized iron wires, each wire covered with tarred tape, is laid on: over this are the usual two servings of tarred hemp, wound on spirally in opposite directions. The weight of this cable in air is $49\frac{101}{112}$ cwt., and in water $25\frac{108}{112}$ cwt. per nautical mile; its breaking strain is $65\frac{100}{112}$ cwt. The price at which this cable has been supplied is £202 per nautical mile.

ELECTRIC CABLES.



The several forms of cables described are shown in *Plate* XXX. *Fig.* 1, shows the single core, unarmoured cable: *a* is the strand conductor, *b* the insulation, and *c* the two servings of tarred hemp, laid on spirally in opposite directions. *Fig.* 2 shows the single core, armoured cable: *a* and *b* are the conductor and insulation as before, *c* the hemp padding, *d*, *d*, *d*, the galvanized iron wires of the armouring, and *e* the two servings of tarred hemp. *Fig.* 3 shows the four cored, unarmoured cable: *a* and *b* are the conductor and insulation, as before. *c* is the padding, and *d* the two servings of tarred hemp. *Fig.* 4 shows the four cored armoured cable: *a*, *b*, and *c* are the conductors, insulation, and padding, as before, *d*, *d*, *d* are the galvanized iron wires of the armouring, and *e* the two servings of tarred hemp. *Fig.* 5 shows the seven cored, armoured cable: *a*, *b*, and *c* show the conductors, insulation, and padding, *d*, *d*, *d* show the iron wire armouring, and *e* the two servings of hemp. *Fig.* 6 shows the special cable, protected, by the strand armouring, each strand of 14 No. 22 steel wires: *a*, *b*, and *c* are the conductors, insulation, and padding, *d*, *d*, *d* are the wires of the strand armouring, and *e* the two servings of tarred hemp.

Defects of multiple cables.

It must be borne in mind that, when a multiple cable is used, and the fuze employed is Abel's, ordinary, mining fuze, (No. 1 Fuze, electric, Abel, or No. 5 Detonator, electric, Abel, of the Service form), any attempt to fire a mine in connection with it by frictional electricity, would be nearly certain to result in the explosion, by induction, of every other mine atttached to the same cable. Experiments have proved that, if several lines of insulated conducting cable are laid in the same trench for a few hundred yards, the inductive effect of the electrical charge, generated by a field pattern Austrian Frictional Machine, is so great, that its discharge, through one cable so placed, is sufficient, not only to fire the fuze in immediate connection with it, but also, by induction, to ignite every fuze in connection with every other cable in the same trench. This effect occurs equally when the cables are several feet apart, provided they lie parallel to each other for a few hundred yards; and whether the shore ends of the cables, the fuzes in connection with which are not intended to be fired, are insulated or put directly to earth, the connections beyond the fuze being to earth, or even when the latter are insulated, provided a very few yards of conductor exist beyond the fuze. Experiments have proved, that such a length as must necessarily be used between a charge and circuit closer, would be quite sufficient to ensure ignition by induction in this way. The current rushes in, as it were, through the fuze, to charge the small length of wire existing beyond it, and causes its ignition.

Induction when frictional electricity is used.

Result of experiments on induction.

The following record of some experiments, tried with a view of ascertaining this inductive effect, gives a very good idea of the danger of using frictional electricity under such conditions :—

Two cables, each consisting of a strand of 7 No. 22 copper wires, insulated with Hooper's di-electric to a diameter of $\frac{3}{16}''$, were laid side by side, on dry ground, for a distance of half a mile, the extremities, to which the fuzes were to be attached, being separated by a distance of 20 yards. When fuzes were fired directly through No. 1 conductor, by a field pattern Austrian, ebonite, frictional machine, fuzes were fired by induction on No. 2 line under the following conditions:—

1st.—With both ends of No. 2 cable to earth, viz., that at the firing station and that beyond the fuze.

2nd.—With the end of No. 2 cable at the firing station insulated, and the connection beyond the fuze to earth.

3rd.—With the end of No. 2 cable at the firing station to earth, and an Abel's fuze, to represent a considerable electrical resistance at this point, introduced between the cable and earth plate, the connection beyond the fuze being, as before, to earth. In this case both the fuzes, one at each end of No. 2 cable, were fired.

The same results were obtained under the three several conditions specified, when two fuzes, in continuous circuit, instead of one, were introduced on No. 2 cable, and again, when three fuzes were substituted, in continuous circuit. These last experiments were tried, in order to ascertain whether the introduction of a considerable electrical resistance into the circuit would overcome the effect of the induced current: with two fuzes, the electrical resistance of the whole circuit would be nearly doubled, and with three nearly trebled, the comparative resistance of the conducting cable being insignificant.

Thc cables were subsequently arranged three feet apart for half a mile, and the experiments, under the three conditions enumerated, repeated: one fuze only being introduced at the distant end of No. 2 cable, and one between the same cable and earth connection at the firing station. With these arrangements both the fuzes on No. 2 cable were fired by induction, as before, on every occasion.

Again a fuze was introduced on No. 2 cable, with three yards of insulated conductor beyond it, the end of this short length being insulated, the cables being, as before, three feet apart. Under these conditions the fuze was fired with the same certainty as in the first experiment.

The object of this last experiment was to ascertain the effect of the induced current on a fuze, with a circuit closer beyond it. The connection with the circuit closer being represented by the three yards of cable, insulated at its outer extremity Subsequent experiments have confirmed the results here described, in a very decided manner, induction having occurred, sufficient to fire an Abel's fuze, when the electric cables lay for half a mile on the ground, 30 feet apart, the other conditions being the same.

Experiments for induction with constant battery.

A constant battery, of 100 cells of Daniell's form, was next employed as the firing agent in connection with No. 1 cable, but no fuze was fired, by induction, on No. 2 cable, under any of the conditions enumerated.

We may therefore assume that such a battery might be used, with safety, to fire any given mine of a system, when the conducting cables lie in close proximity and parallel to each other for a considerable distance, or when a multiple cable is used.

The fuzes used were of Abel's most sensitive form, (No. 1. Fuze, Electric, Abel), and the experiments, while establishing beyond a doubt the powerful inductive effect of a discharge of frictional electricity, gave substantial proof of the great delicacy of these very sensitive fuzes, and of their good qualities as simple agents of electrical ignition; at the same time, rendering it very evident that the utmost care is indispensable in testing and using them.

The inductive effect with a multiple cable would manifestly be very much increased, as compared with the experiments here detailed, in consequence of the proximity of the adjacent conductors. *Frictional electricity* must not therefore be used to fire charges in connection with a multiple cable, or even when separate cables lie parallel to each other for a short distance, in connection with any system of submarine mines, when No. 1 Fuze, Electric, Abel, or No. 6 Detonator, Electric, Abel, is employed.

Induction does not occur to such an extent as to fire the above fuze, when a suitable constant battery is employed. Such a battery may therefore be used with perfect safety, to fire any particular mine of a system attached to a multiple cable, without endangering the others. With the platinum fuze, the electrical resistance of the bridge being very small, there would be practically no danger of ignition by induction. Recent experiments have proved that Abel's Submarine Fuzes, (No. 2. Fuze, Electric, Abel, Submarine, and No. 6. Detonator, Electric, Abel, Submarine), are much less likely to be fired by an induced current, than those with which the above experiments were made, and when used in connection with a firing battery, in the combination approved for the authorized system of submarine mines, they are perfectly safe in this respect.

Junction box for connection of lines to multiple cable.

In order to facilitate the connections of the several separate lines, diverging from the extremity of a multiple cable, a junction box has been designed. Into one angle of this box the multiple cable is introduced, while the separate cables make their exit on the opposite sides, and pass thence to the several mines of the system.

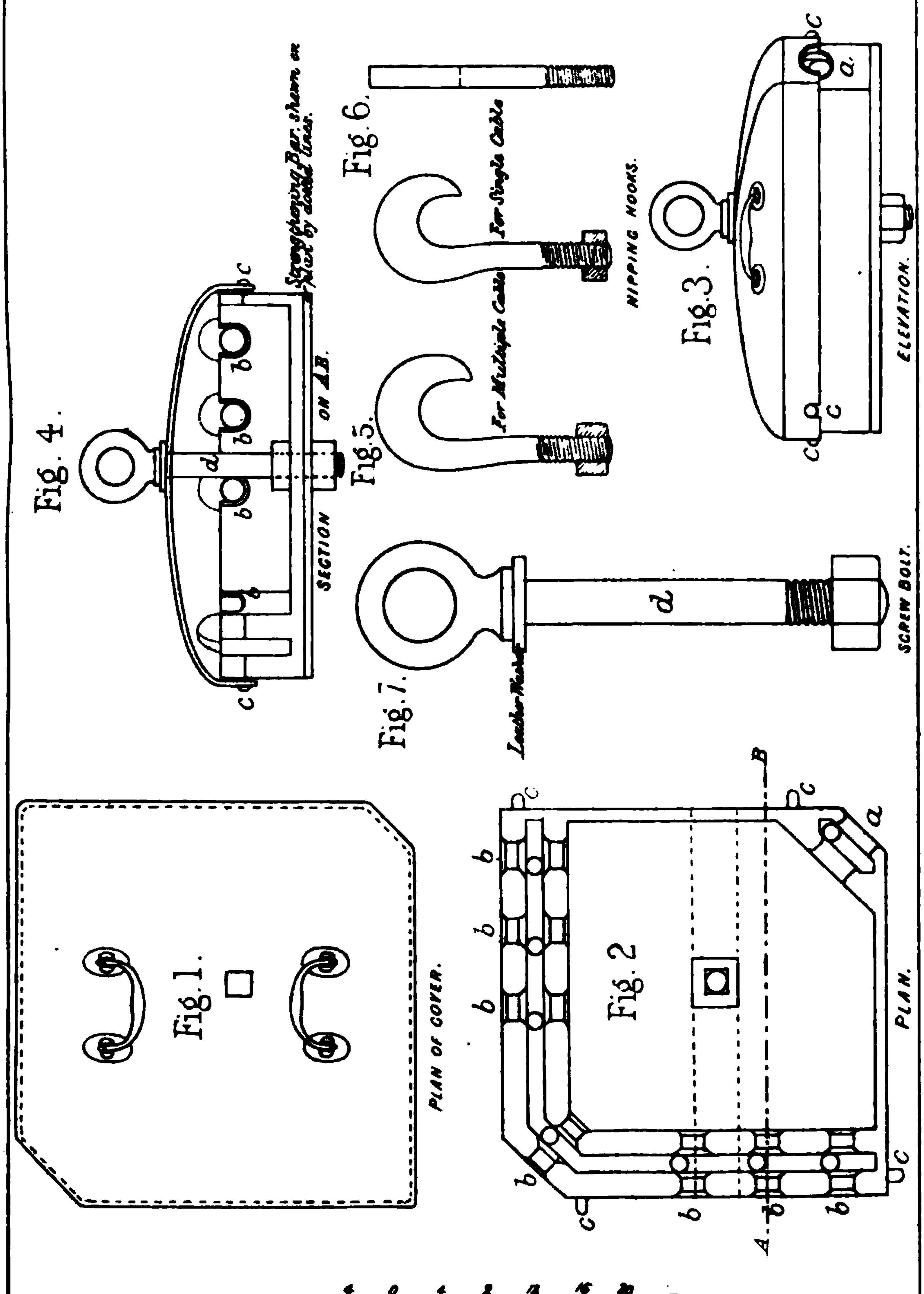
Plate XXXI., shows the details of the junction box approved by the Torpedo Committee, and which has been used, with success, for many months, in connection with the system of mines now under experiment at the Nore. *Fig.* 1 shows a plan of the top

and *Fig.* 2 a plan of the bottom of the apparatus: *Fig.* 3 shows an elevation and *Fig.* 4 a section of the whole. The multiple cable is introduced into the box at the angle *a* and secured there by means of a nipping hook, shown in *Fig.* 5, passing through the bottom of the apparatus and made tight by means of a nut, fitting on to the threads of a screw at its extremity: the nipping hook works in a groove and the cable is carried on the sides of this groove, the openings for it being made large enough to allow it to pass in very freely, and the bearings being rounded, to prevent injury to the armouring should any slight motion occur. As a matter of precaution, the points where the cable rests may be served round with spun yarn. The single cables radiate from the junction box, through the openings *b*, *b*, *b*, on the sides and angle opposite the multiple cable. Each multiple cable carries seven single cores, and each of these is connected, by means of an insulated joint, in a manner to be hereafter described, to the core of a single cable passing to each mine of a group. Nippers of smaller size, as shown in *Fig.* 6, are provided to grip the single cables, which are secured in a manner precisely similar to the multiple cable. When all the connections described have been made, the top is laid over, so as to rest on the studs *c*, *c*, *c*, and very firmly secured by a bolt *d*, shown in *Fig.* 7, made tight (not watertight) by a washer and nut. A buoy is connected to the top of the bolt *d*, by means of a $\frac{1}{4}$-inch chain, or 2-inch wire rope, and shackle, so that the whole may be lifted together when required for examination. A chain or rope of this form, is sufficiently strong to carry the weight of the junction box and cables, enough slack being left in the latter to allow the apparatus to be brought to the surface. The bolt *Fig.* 7 is made with a square section, to prevent any chance of its being turned round after submergence, which might disconnect the bottom from the top. The whole strain due to the weight of the junction box and cables, is borne by the several nipping hooks, which are made sufficiently strong for this purpose: no strain is brought upon the insulated connections of the cores within the box.

A circuit closer jacket may be used as a buoy for this purpose with advantage. It possesses ample buoyancy, and being similar to the other objects which might appear at low water, it would not be so likely to attract much notice. This junction box must be placed in such a situation as to be easily attainable, even in the presence of an enemy's blockading squadron, and the buoy attached to it must not be conspicuous. It is essential that it should be in a safe and well guarded position, as any injury to it, or to the multiple cable, would be fatal to every mine connected with it. The necessity for safety would also regulate the length of the multiple cable, and the point at which the separate cables should diverge: this must always be dependant on local circumstances.

JUNCTION BOX,

FOR 1 MULTIPLE & 7 SINGLE CABLES.



Scale 4 0 4 8 12 16 20 of Inches.

FOR FIG. 1. 2. 3 & 4.

Lithographed at the S. M. E. Chatham.

B. Butler, Corpl. R.E.

Cable with branches, suggested by Qr.-M.-S. J. Mathieson, R. E.

Q.-M. Sergt. J. Mathieson, R.E. has suggested a system of electro-contact mines, each separate charge being placed on a branch from a single main electric cable. An attempt was made to construct a special cable for use in this way. No difficulty was experienced in forming a branch on the copper conducting wire, but the process of insulating and arranging the wire armouring of the branch connections, commencing at the point where the insulation and armouring of the main cable had necessarily been removed, in order to form the branch conductor, was found to be extremely troublesome. It was necessary to do it by hand, which proved expensive, and, after all, the results were at best unsatisfactory. This special form of cable was consequently abandoned, and the branch system of mines arranged to be worked in another way.

Principles of branch electro-contact system.

The principle, on which the electro-contact system of mines, on branches from a single cable as suggested by Q.-M. Sergt. J. Mathieson, R.E., is arranged, is dependant on the use of a platinum wire fuze, in connection with a platinum wire bridge in each branch, close to its junction with the main cable. On the passage of a quantity current this platinum bridge would be fused, and the mine itself fired, simultaneously, and the bridge being within an insulated and watertight apparatus, the branch conductor of the expended mine would be cut off and insulated, thus leaving the battery free to act with its full power, through any other mine attached to the same main electric cable. Experiments have proved this system to be very efficient. The apparatus in which the platinum wire bridge is enclosed, has been called a disconnector: its details, as well as those of the whole system, shall be explained hereafter. A supply of platinum wire fuzes, disconnectors, and other apparatus required for the electro-contact branch system, has been provided in the reserve of stores for service.

Plan proposed as a substitute for mechanical mines.

This plan has been proposed as a substitute for the mechanical self-acting system. It enables us to get rid of that element of equal danger to friend and foe, which is inseparable from any purely mechanical method. It is easily seen that, by it, perfect safety is secured to a friendly vessel by simply detaching the firing battery. We are thus enabled to limit the use of mechanical submarine mines very strictly, to positions where they are only likely to injure an enemy, and thus to eliminate one great source of danger to our own ships.

Connecting box for 7 cored, armoured, multiple cable.

Special connecting boxes have been provided to meet the following contingencies. 1st.—that of a 7 cored, armoured, multiple cable, to be connected direct to another length of the same. 2nd.—that of a single, armoured cable, to be connected direct to another length of the same; and 3rd.—the T connecting box, for the branch system of electro-contact mines, already alluded to. These, together with the platinum wire disconnector, for use in the latter combination, are shown in *Plate* XXXII.

Fig. 1 shows the connecting box for a 7 cored, armoured, multiple cable in plan. It consists of a pair of cast iron plates, of precisely similar form, so made as to be capable of being fastened tightly together by means of four bolts with nuts and screws. The grooves at the two extremities are just sufficiently large to grip the armoured cable very firmly, when the upper and lower portions have been screwed together. A larger space is provided in the hollow within, in which the joint between the two lengths of cable is placed. *Fig.* 2 shows a section through this connecting box on the line M N, in this section the smaller grooves at the ends are shown in elevation. In order to prevent the extremities of the two sections of cable slipping out, a turk's head is formed on each, as shown in *Fig.* 6, to fit inside the connecting box at its extremities, the actual joint of the conductor and insulation being within. The turk's head is made by turning back the wires of the cable armouring, and frapping them firmly round with spun yarn till the requisite size is attained.

This box answers perfectly well for the connection of two lengths of the four cored armoured cable, the only precaution to be taken for this purpose being, to make the turk's heads sufficiently large to prevent them slipping through the grooves at the extremities of the connecting box, and to continue the spun yarn frapping sufficiently far down the cable, and to make it thick enough to ensure a strong grip at the points where the cables enter the connecting box.

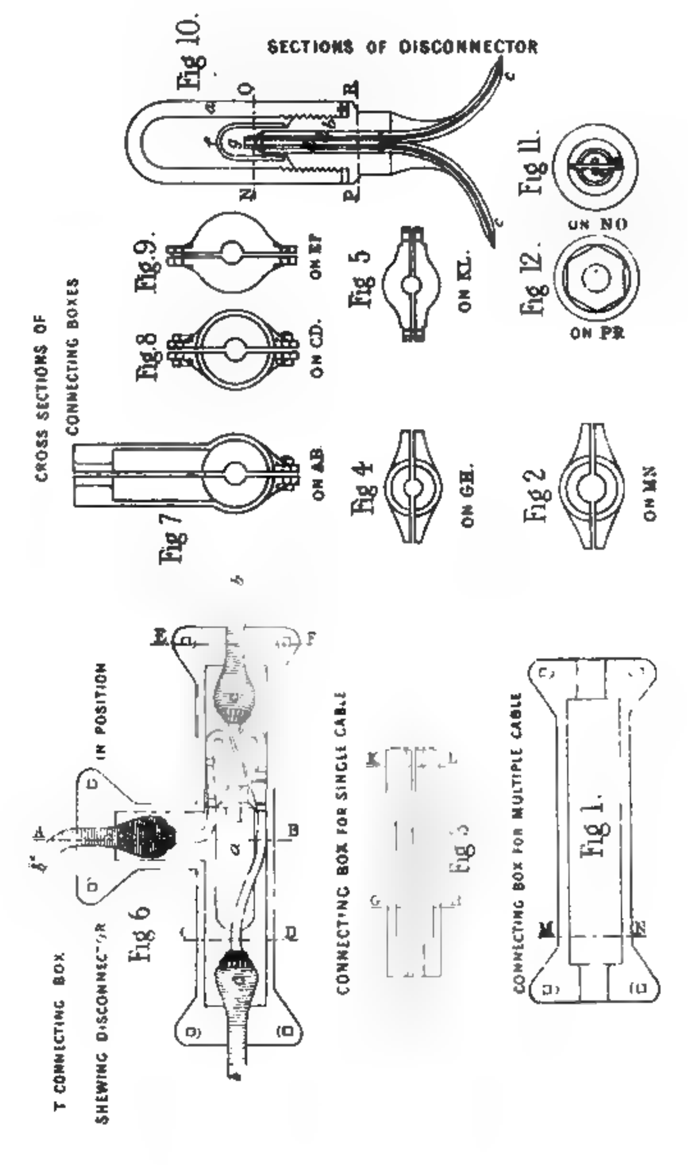
Connecting box for single armoured cable.

The form of connecting box, for use with two lengths of single armoured cable, is shown in section in *Fig.* 3. This, like that just described, consists of two cast iron plates, of a size to fit the particular form of cable, and capable of being fastened tightly together by means of bolts with screws and nuts. *Fig.* 4, shows a section through the central portion of this apparatus, on the line G H; and *Fig.* 5 a section through one of the ends, showing the connecting screws and bolts, on the line K L. The joint of the single armoured cables is made in precisely the same manner as that for the multiple cables, turk's heads being formed on the extremities of the cables to prevent them drawing out of the box, and to prevent the wires of the armouring, at the point where they have been removed in order to form the insulated joint, from projecting in such a way as to injure the di-electric. The details of the cable joints shall be described in treating of the subject of insulated joints.

T connecting box.

A plan of the T connecting box, for use with the branch system, suggested by Qr.-Mr. Sergt. Mathieson, R.E., is shown in *Fig.* 6. This, like the others, consists of a pair of cast iron plates, capable of being firmly joined together by bolts with screws and nuts, the only difference being in the T form, which necessitates three pairs of screw bolts and nuts, instead of two as in the other forms. In all cases the bolts are made with a square section and pass through square holes, to prevent any chance of turning after

CONNECTING BOXES & DISCONNECTOR.



Lithographed at the S. M. E. Chatham — *B. Butler, Corp^l R. E.*

the two portions of the connecting box have been screwed together, and thus to ensure a certain and firm grip on the cables. *Fig.* 7 shows a section through the T connecting box on the line A B. *Fig.* 8 a section through the same on the line C D; and *Fig.* 9 a section on the line E F. In *Fig.* 6, *a* is the disconnector, for use with the platinum wire fuze on the branch; *b, b & b'* are the armoured, electric cables, *b, b* being the main and *b'* the branch cables, in connection with the forked joint formed within the T connecting box; *c, c, c* are the turk's heads, formed on the extremities of the cables, as already described.

Disconnector

The details of the disconnector are shown in section in *Fig.* 10. *a* is an iron dome or cover, provided with a screw, fitting on to a corresponding screw on the ebonite body *b* of the apparatus; when screwed tightly down upon the washer *i*, the whole is made perfectly watertight. The washer *i* is composed of canvas prepared and made waterproof with indian-rubber. *c, c* are insulated terminals, for attachment to the cores of the main and branch cables, after the armouring has been removed, as shown in *Fig.* 6. *d, d* are two copper conducting wires of No. 16, B.W.G., passing through the centre of the ebonite body and projecting into the interior of the apparatus :—these wires are held in position, in the centre of the ebonite body, and insulated from each other by means of a composition, consisting of 16 parts of pitch, 2 of tallow, 2 of beeswax, and 2 to 4 of gutta percha; this composition is put in hot and, when cool, becomes hard and durable; it becomes plastic at about 160° Fah., and it is consequently capable of standing a considerable degree of heat without injury: in putting it into the hollow of the ebonite body round the copper wires, care is necessary to ensure that the whole cavity may be completely filled up, as the slightest imperfection renders the apparatus subject to leakage, from the pressure of water at the depth at which it is likely to be used in practice. It is necessary to test the apparatus carefully, to ascertain that it is watertight in this, as well in other respects, before it is connected for use. *f* is a boxwood cover, slipped on and fitting, with a moderate degree of tightness, to the top of the ebonite body *b*. *g* is a piece of thin platinum wire, weighing 1·6 grains to the yard, and $\frac{4}{10}$ inch in length. *h* is an ebonite pin, passing through two small holes in the boxwood cover, into which it fits tightly in such a position as to be beneath the platinum wire bridge *g*, when the boxwood cap is on. The ebonite pin *h* is pushed through the holes in the cover *f* from the outside, so as to pass beneath the bridge *g*, after the priming has been inserted and the cover has been pushed on. *Fig.* 11 shows a section on the line N O; and *Fig.* 12 a section on the line P R, through the apparatus.

Mode of action.

When prepared for use, the thin platinum wire bridge *g* is surrounded by loose gun-cotton priming, sufficient in quantity to blow off the boxwood cover *f*, without destroying the outer dome *a*;

Captain David's plan of combining an electric cable with a boom.

His idea was to lay one or more of such rope protected electric cables along the whole length of the boom, carefully attaching them thereto. With such an arrangement any attempt to break the boom must be accompanied by a fracture of one of these cables; and the bare extremity of the conducting wire, falling into the water as soon as the cable was cut through, would be sufficient to complete the circuit of a battery, one pole of which was attached to the cable with the other to earth. It is easily seen how a charge previously placed in such a circuit would thus be fired, and would destroy any vessel or boat in its vicinity. It would only be necessary to insulate the extremity of the cable beyond the charge, as regards the firing battery, to render the system inactive till the cable was cut. It is, no doubt, probable that this cable, resembling in outward appearance an ordinary rope, would not excite suspicion and would be likely to be cut, but any mine in connection with it, near enough to injure a vessel or boat, would also generally be near enough to damage the boom itself, a result which would not be at all desirable. Some experiments were tried by Captain David, which demonstrated the practicability of the idea, as far as the firing of a charge is concerned.

Such a combination useful as an indicator.

As an indicator of the continuity or otherwise of a boom, at night or in a fog, it would probably be useful. The arrangement of an insulated cable, for such a purpose, would be the same as that for firing a mine, but instead of a charge of powder or guncotton, a galvanometer would be introduced into the circuit, and a fracture of the conductor, dependent on the breakage of the boom by storm or an enemy's operations, would at once be indicated by a deflection of that galvanometer, consequent upon the current from the battery, the circuit of which would be completed, through the severed cable, as before. In this manner a most effective watch, from the interior of a fort, could be kept over obstructions in a channel, even though such obstructions were perfectly invisible from any cause whatever.

Improvised electric cables.

The electric conducting cable is perhaps the most important item in any system of electrical submarine mines; an accident to it would nearly always render a mine ineffective: it is therefore a difficult matter to treat of, in reference to any improvised arrangements that may be practicable. As a general rule, in the event of the more approved forms of cable not being obtainable, the best conducting wire and insulator at hand should be used; and, bearing in mind the conditions to be fulfilled, already enumerated, it should be most carefully tested, under a considerable pressure of water, before being employed; any of the ordinary forms of conducting wire insulated with gutta percha might, with the addition of some external protecting covering, be made available, or even a wire insulated with a thick covering of well tarred canvas might answer for a short distance. In

forming an impromptu electric cable, a large conducting wire, of small electrical resistance, should be selected. The reason of such a selection is manifest, with reference to the well known law of division of electrical currents.

CHAPTER VIII.

Watertight & Insulated Joints & Connections.

The next point to be considered, is the mode of carrying the conducting wires and attached fuzes into the charge, so as to ensure a watertight joint, and keep the arrangement in proper condition for ignition at any moment required.

The great object is to exclude the water: this was effected in the Austrian apparatus by means of a stuffing box.

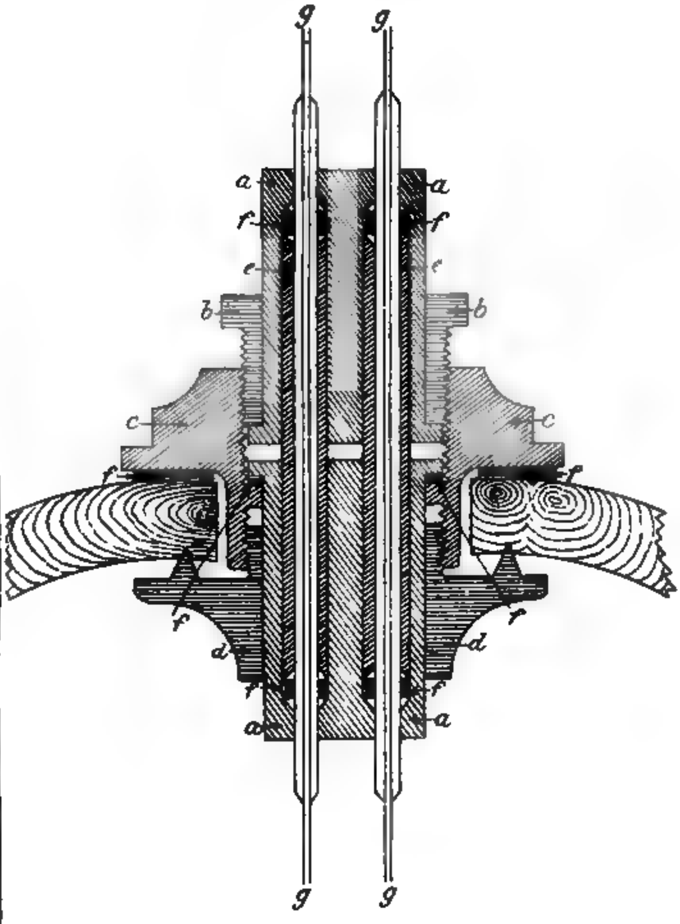
Mathieson's method of introducing fuzes into a charge.

Among the first ideas for the introduction of the fuzes and their connections into a charge, in such a manner as to preserve a thoroughly watertight joint, and yet to retain the power of taking the apparatus out with facility, for examination, and of restoring it quickly to its position in the mine, was that designed by Qr.-Mr. Sergt. J. Mathieson, R.E. The details of several forms of this apparatus, to meet certain requirements, were worked out by him and that shown in section in *Plate* XXXIII., gives the general principles on which all his first designs were constructed.

This form of apparatus was intended for carrying the conducting wires into a charge placed in an ordinary wooden barrel. There being no iron here to decompose, the screws, &c., may be made of brass, which is an advantage, as this latter metal is more easily worked into the form required; *a*, *a* are the two ebonite cylinders, with shoulders to receive a brass coupling screw *b*, &c.; *c* is a brass socket, in connection with another brass screw *d* within the barrel; *e*, *e* are the ebonite tubes, *f*, *f*, *f*, *f* are indian-rubber washers, and *g*, *g* the insulated conducting wires to connect the fuze. The screw *d* is furnished with spikes, which grip the inside of the barrel and secure rigidity. The mode of applying the apparatus is easily understood. The portion *d* is first placed within the barrel, and screwed tightly up against its inner surface, by means of the screw socket *c*, so that the spikes on *d* may take hold of the barrel, while the part *c* is brought firmly down on the indian-rubber washer *f*, so as to exclude water at this point. The lower ebonite cylinder *a* is then dropped into its place, over another indian-rubber washer, fitting on a small

FUZE PIECE, DESIGNED BY

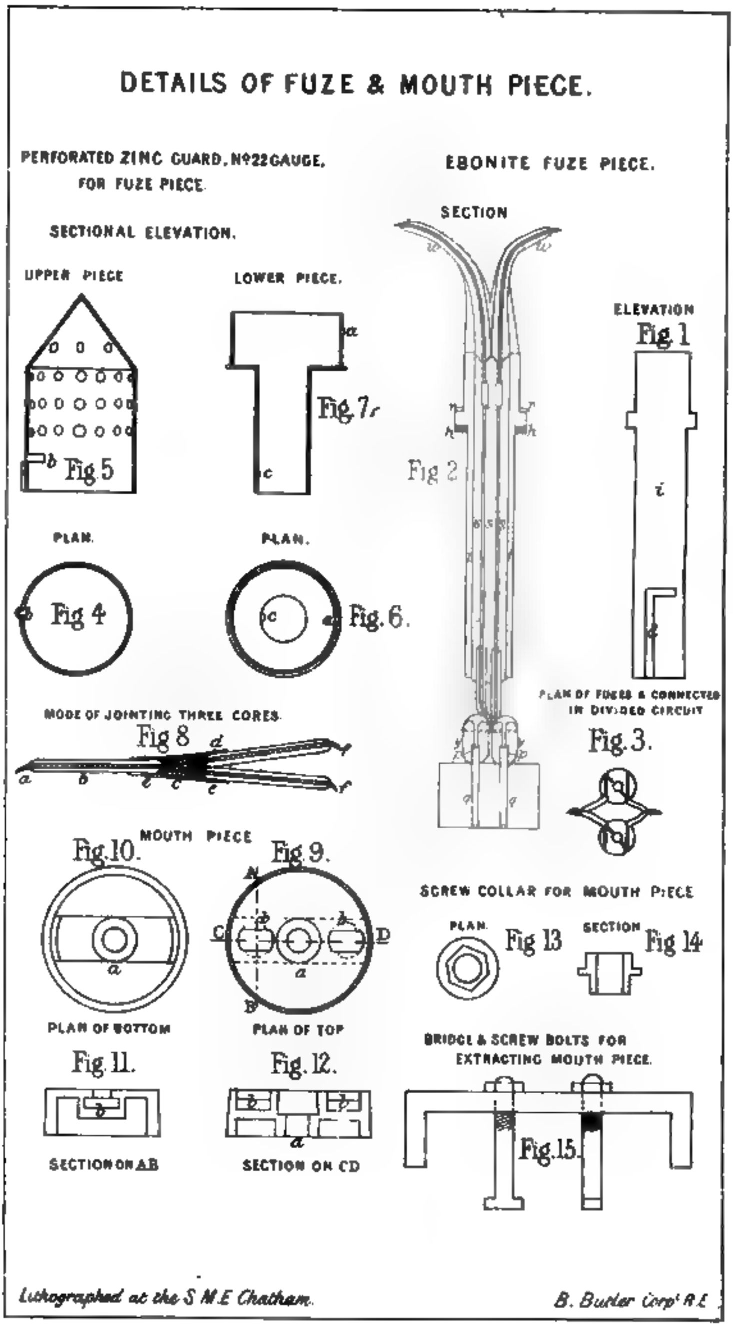
Q^R M^R SERJ^T MATHIESON.



Lithographed at the S M E Chatham

B Butler, Corp^l R.E.

PLATE XXXIV.


DETAILS OF FUZE & MOUTH PIECE.
PERFORATED ZINC GUARD, No. 22 GAUGE, FOR FUZE PIECE.
SECTIONAL ELEVATION.
UPPER PIECE
LOWER PIECE.
Fig 5
Fig. 7.
PLAN.
PLAN.
Fig 4
Fig. 6.
MODE OF JOINTING THREE CORES.
Fig 8
MOUTH PIECE
Fig. 10.
Fig. 9.
PLAN OF BOTTOM
PLAN OF TOP
Fig. 11.
Fig. 12.
SECTION ON AB
SECTION ON CD
EBONITE FUZE PIECE.
SECTION
Fig 2
ELEVATION
Fig. 1
PLAN OF FUZES & CONNECTED IN DIVIDED CIRCUIT
Fig. 3.
SCREW COLLAR FOR MOUTH PIECE
PLAN.
Fig 13
SECTION
Fig 14
BRIDGE & SCREW BOLTS FOR EXTRACTING MOUTH PIECE.
Fig. 15.
Lithographed at the S. M. E. Chatham.
B. Butler Corpl R.E.

shoulder on the screw socket *c*, the fuzes having been previously attached to the insulated conducting wires *g*, *g*, which latter are passed through the thick indian-rubber discs *f*, *f* within the lower cylinder: the ebonite tubes *e*, *e* having been passed into their places, over the insulated wires *g*, *g*, the upper cylinder *a* is next slipped over the insulated conducting wires, similar indian-rubber discs having been pushed over them within the upper cylinder: practically it is convenient to put the cylinders *a*, *a*, the tubes *e*, *e*, the thick indian-rubber discs *f*, *f*, and the insulated conducting wires *g*, *g*, together and to attach the fuzes and drop the whole complete into the socket *c*. It only then remains to pass the coupling screw *b* into its place and screw it up tightly with a spanner, thus bringing a considerable pressure upon the washers within the ebonite cylinders *a*, *a*, as well as upon that on the shoulder of the screw socket *c*. It is easily understood how the whole may thus be made perfectly watertight. The operation of introducing a fuze into a charge, or of withdrawing it for examination, may in this way be very rapidly performed.

Approved form of fuze and mouth piece for service cases.

Qr.-Mr. Sergt. Mathieson designed a very similar form of apparatus to that shown in *Plate* XXXIII., for use with a metal case, and the general ideas embodied therein have been preserved in a modification of this, which has been approved as the mouth and fuze piece for all classes of metal cases, as now adopted for submarine mining service.

The general construction of the service fuze and mouth pieces is shown in section in *Plate* VI., *Fig.* 1, page 55: the details are now given in *Plate* XXXIV. *Fig.* 1 shows an elevation of the ebonite body, and *Fig.* 2 a section of the ebonite fuze piece complete. It is formed of an ebonite cylinder *i*, provided with a small shoulder, made to fit, over a leather washer *h*, against a corresponding shoulder in the metal mouth piece: a brass collar *r* is provided below the ebonite shoulder of the ebonite fuze piece, to receive the pressure of the coupling screw, used in fixing it firmly into its place, and to prevent the metal screw working directly on to the ebonite, by which process the latter might be injured. Two copper wires *v*, *v* of No. 16 B.W.G. are passed through a hollow, left in the centre of the ebonite fuze piece, and held in position and insulated from each other by means of waterproof composition *s*, *s*, *s*, consisting of 2 of tallow, 2 of beeswax, 16 of pitch, and 2 to 4 of gutta percha, pressed into it in a melted state: in filling up the hollow with this composition, care is necessary to prevent the smallest crevice, through which moisture could possibly find its way into the interior, as the slightest ingress of moisture might be fatal to the insulation. *w*, *w* are a pair of insulated, copper, wire terminals, soldered on to the conducting wires *v*, *v*, within the fuze piece, and carefully insulated, at their entrance into the latter, by means of indian-rubber tape cured on. The fuzes are connected with the fuze

piece, by means of two short lengths of insulated conducting wire, projecting from the extremity of the latter. *y*, *y* show the wooden fuze heads, *p*, *p* the electrical priming of powdered graphite and fulminate of mercury, resting between the wire terminals of the fuze; *q*, *q* are the long metal cones, containing the priming of fulminate of mercury, inserted into the holes left for that purpose in the priming disc *q* of gun-cotton.

Connection of fuzes. Two fuzes are always used in each charge, so as to ensure, to the utmost extent, certainty of ignition when the electric current is passed. When the high tension detonating fuze for submarine service, (No. 6 detonator, electric, Abel, submarine), is used, the two fuzes should be connected up in divided circuit as shown in *Fig.* 3. When detonating platinum wire fuzes, (No. 7 detonator, electric, platinum wire), are employed, they should be connected up in simple continuous circuit. *Fig.* 4 shows a plan, and *Fig.* 5 a sectional elevation, of the perforated top of the zinc guard covering the fuzes and gun-cotton priming. *Fig.* 6 shows a plan, and *Fig.* 7 a sectional elevation, of the lower portion of the zinc guard; this lower portion fits on to the ebonite frame of the fuze piece and is held in position thereon by means of a stud *c*, *Figs.* 6 & 7, working in a groove in the latter shown at *d*, *Fig.* 1. The perforated top is passed on to the lower portion, after the fuzes and gun-cotton priming have been fixed in position, and is held fast by a bayonet socket arrangement, *b*, *Figs.* 4 & 5, working on a stud, *a*, *Figs.* 6 & 7, projecting from the side of the lower portion of the zinc guard.

Perforated zinc guard for fuzes,

Forked joint. *Fig.* 8 shows in section, the details of the mode in which the forked joint connection, shown in *Fig.* 1, *Plate* VI., for the attachment of the electric cable from the circuit closer, to the conductor to the fuze and to the electric cable from the shore, is made. *a* is the conductor of the electric cable from the shore, *b* being the insulation of the same, stripped of its outer hemp covering and protecting armour. *f*, *f* are the conductors of the insulated cable leading to the circuit closer, and of the connection to the fuze piece. The three conductors are firmly twisted together, as shown in the figure, and soldered: over them the insulation of indian-rubber tape *c*, is then laid on, in a manner to be hereafter described. A piece of indian-rubber tubing *d*, which must be passed on to the core of the cable *a*, before the metallic connection of the three conductors has been made, is then drawn over the joint and firmly whipped on with strong twine at the points *e*, *e*. Before making this joint all hemp covering and everything of a nature likely to afford a path for moisture, must be carefully removed from the cores to be connected.

Mouth piece. *Fig.* 9 shows a plan of the top, and *Fig.* 10 a plan of the bottom, of the mouth piece for the service pattern case; its position ready for service is shown at *f*, *Fig.* 1, *Plate* VI., *Fig.* 11 shows a section on A B, and *Fig.* 12 a section on C D,

PLATE XXXV.

TEMPORARY WATERPROOF MOUTH-PIECES.

Fig.1.

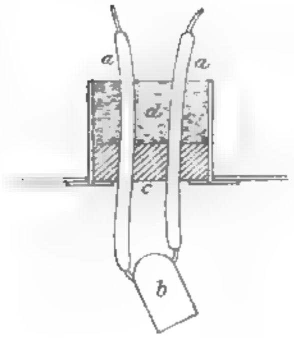


Fig.4.

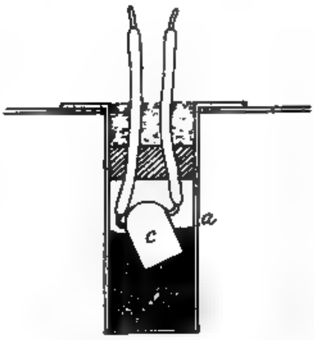


Fig.3.

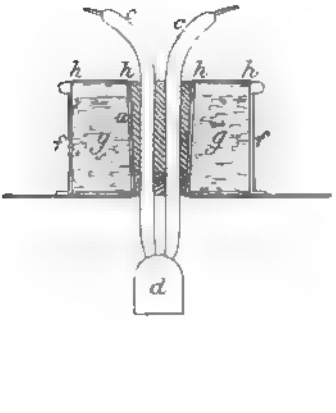
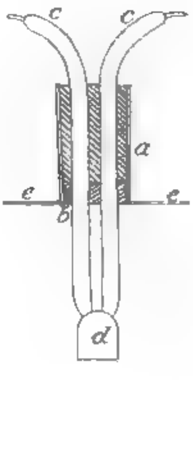


Fig.2.



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through the same. *a* is the circular opening for the reception of the ebonite fuze piece. *Fig.* 13 shows a plan, and *Fig.* 14 a section, of the screw collar used to hold the ebonite fuze piece in position, the thread of the screw collar fits into a female screw on the inner circumference of the circular opening *a*. *b*, *b* are two holes made in the top of the metal mouth piece, for the reception of the bolts used in extracting it, when it becomes necessary to unload the case or to take the fuzes out for examination. In order to make it watertight, the mouth piece itself must be very tightly pressed down against the hollow shoulder made to receive it, by means of the screw collar *e* shown in *Plate* VI., *Fig.* 1, and considerably more force than can be readily applied by hand, is necessary again to withdraw it. For this purpose, therefore, a bridge, *Fig.* 15, provided with two screw bolts, made to fit into the hollows *b*, *b* in the mouth piece, must be used. The bridge itself having been placed over the mouth piece, the screw bolts are inserted and turned round so as to obtain a proper hold, and a few turns of the nuts draw up the mouth piece, however tightly it may have been pushed in.

Temporary waterproof connection.

In ordinary submarine blasting, when the charges are not required to be submerged for any considerable time before they are fired, or when a good form of fuze piece is not to be had, the composition, viz., 2 of tallow, 16 of pitch, 2 of beeswax, and from 2 to 4 of gutta percha, may be used and will be found very effective. The vessel or can in which the charge is to be placed, having been formed with a shoulder or neck, *Plate* XXXV., *Fig.* 1, of sufficient size to receive a moderately large bung, the insulated conducting wires *a*, *a* having first been attached to the fuze *b*, are passed through two holes in the bung *c*, which latter is passed into the neck, which it should fit tightly, and the above composition is then pressed into the space *d*, above it. This composition soon becomes hard and renders the whole watertight. It is amply sufficient for all charges to be fired soon after submersion. It becomes plastic at about 160° Farenheit.

Much care necessary in sealing charges with heated composition.

This composition may be used without the gutta percha, and becomes plastic under such circumstances at a temperature of about 150° Farenheit. The addition of a little gutta percha hardens it and renders it less likely to be affected by atmospheric heat. More care is, however, necessary in using it, after the gutta percha has been added, because the higher the temperature the nearer it approaches to the igniting point of an explosive, and it may be superheated without indicating the fact by any outward appearance. For this latter reason, gutta percha should never be used by itself to seal up the bungs or connections of loaded cases, if it can possibly be avoided. Serious accidents have, on more than one occasion, occurred when it has been used for this purpose. When using any of the new forms of explosive, which ignite at comparatively low degrees of heat, or even with

gun-cotton, the temperature, at which the composition used to seal up a charge becomes sufficiently plastic, is a matter which must be most carefully considered.

Arrangement with clay joint.

An improvement upon this plan is shown in section in *Plate* XXXV., *Figs.* 2 and 3; *a*, *Fig.* 2, is a tin socket, in the form of a very long truncated cone, with shoulders to support the cork *b*, through which the insulated terminals *c*, *c* pass to the fuze *d*, and with an outside rim or shoulder *e*, *e* to fit into the nozzle *f*, *f*, *Fig.* 3, of the case to contain the charge. The fuze, wires and cork having been inserted into the socket *a*, *Fig.* 2, as already described, the top is filled in with waterproof composition (16 of pitch, 2 of beeswax, 2 of tallow, and from 2 to 4 of gutta percha), shown dark in the sections—this is done before the fuze is brought near the charge, and there is consequently no danger incurred from heat. The socket, complete with fuze, &c., is next inserted in the nozzle *f*, *f*, *Fig.* 3, and moist clay *g* is carefully pressed in over it, to fill up and keep it steady in its place. A disc of tin, perforated in the centre, so as just to pass over the top of the socket, is then placed over the top of the nozzle *f*, *f* of the case, which it is made to fit, and its outer and inner rims, at *h*, *h*, *h*, *h*, are made watertight by soldering. During this operation of soldering the heat is thus kept well away from the charge, and separated from it by the moist clay, &c., so as to be perfectly safe. This arrangement was always used, during the summer of 1869, in carrying on gun-cotton experiments in the Medway, and scarcely an instance, out of a large number of charges fired, occurred in which water found its way through it.

Arrangement of fuze in a separate compartment.

One mode in which the charge may be kept dry is to introduce the fuze into a small compartment, let in, as it were, but totally separate from the charge, as for example, in *Plate* XXXV., *Fig.* 4, a tube *a* of tin, made quite watertight, may be introduced into the charge, which however it should completely separate from the priming powder *b*, in contact with the fuze *c*, the remainder of the tube being filled in as before with a bung and waterproof composition. The effect of firing the fuze in this case is to burst the tin tube *a*, by means of the priming powder *b*, and thus ignite the mine. This may do well enough for small charges, say up to 50lbs. or 60lbs., but for larger masses, it is always preferable to have the fuze in actual contact with the charge itself.

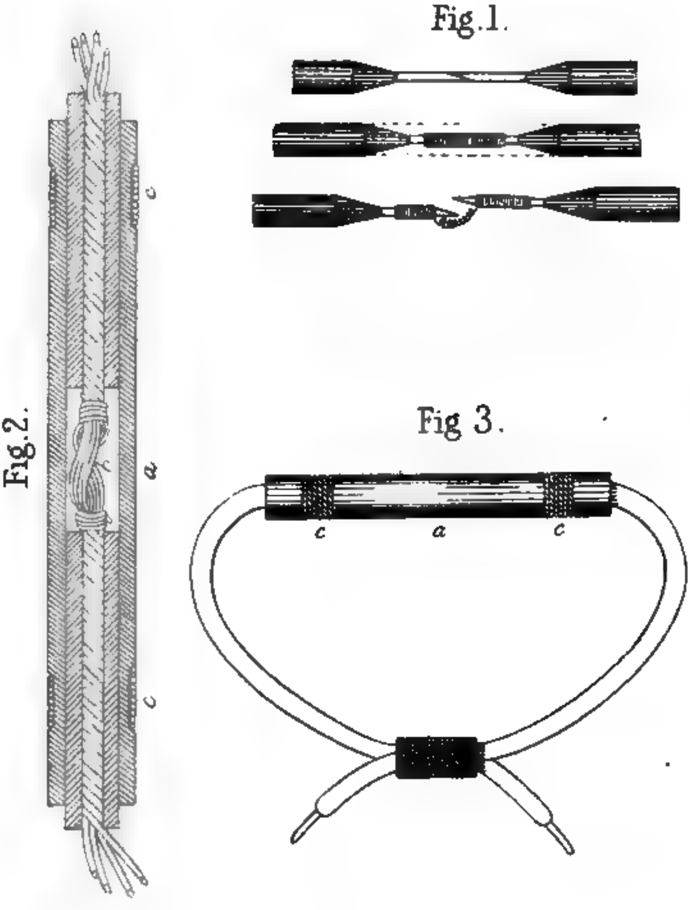
The object of this arrangement is to save the main body of the charge, in the event of any leakage of water through the opening left for the fuze; it was formerly much used in submarine explosions, but we are now able to make such good watertight connections, that it seems to be almost an unnecessary precaution under ordinary circumstances.

Fuzes must always be

In all cases, the fuze or fuzes should be carefully tested electrically, before they are placed in a charge, and this testing

PLATE XXXVI

INSULATED JOINTS.



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B Butler, Corpl R E

should be done both singly and in a group, arranged in the same combination in which it is proposed to use them in the mine itself, and they should be subsequently tested after being placed in the charge. *tested before and after being placed in charge.*

Next as regards the best mode of making an insulated joint in a cable. Several systems have been recommended and have proved perfectly effective. *Joints.*

For a permanent joint, we have the ordinary gutta percha and indian-rubber joints, which under certain circumstances, would be very useful for submarine purposes. These are somewhat troublesome to make, and would require a considerable time to render them sufficiently good for the purpose required. They must be made deliberately and are similar to those used for ordinary submarine telegraph cables. The mode of making such insulated joints, as recommended by the Indian-Rubber, Gutta Percha and Telegraph Works Company, Silvertown, North Woolwich, is as follows:—For a gutta percha cable, remove about $1\frac{1}{2}$ inches of the insulation at the ends. After warming gently it is easily pulled off with the fingers, (this is much safer than cutting); clean the two ends with emery cloth, and file a $\frac{1}{2}$ inch scarf on them, *Plate* XXXVI., *Fig.* 1. The wires are then caught, with the scarfs together, in two small vices, fixed on a bench, one working on a slide, so that they can be set at any required distance apart, and soldered. After soldering, clean the scarf off with a small file. Then bind it round with four strands of fine copper wire, laid side by side; loop one end on the left hand vice, and wind from left to right, taking care that the wires are evenly laid on and do not ride over each other; the length of the binding should be about $1\frac{1}{4}$ inches; the ends of the binding wires are now snapped off by a sharp tug with the pincers. This binding is then soldered at the centre, and at the ends, leaving two parts of the binding unsoldered, so that if the scarf be drawn asunder the 4 strand wire shall still connect the two ends and form a metallic circuit. *Permanent joints in cables.* *Permanent gutta percha joint.*

The joint is then well washed to remove all acid from the copper.

In scarfing a strand conductor, the two ends are first soldered making them solid. If the diameter of the conductor exceed No. 14 gauge two courses of binding are used, the first soldered all over, the second in the centre and ends only. This is the mode adopted for submarine telegraph cables, but for the comparatively short lengths used for submarine mining purposes, an efficient metallic connection may be made, in the case of a strand conductor, by simply twisting the wires, of the two portions to be joined, tightly together, after cleaning them, and soldering. Care must be taken to prevent any projecting ends of wire remaining at the junction. *To scarf a strand conductor.*

To complete the insulation, clean the joint all over with a little

To complete insulation. spirit of naptha on a rag, and give it a thin layer of Chatterton's compound, warm the joint in the flame of a spirit lamp, and taper the gutta percha, by drawing it gently with the fingers until it nearly reaches the centre, then with a hot tool, designed for the purpose, work the two portions together to form a solid mass. Then apply a thin layer of compound, followed by a strip of sheet gutta percha $\frac{1}{8}''$ thick, and large enough to cover the whole, warmed, together with the joint, and lapped round it, taking care to expel the air in front. When the two edges meet cut them off as close as possible with a pair of scissors and work them into one another with the tool, doing the same at the ends, then gently warm the whole, and burnish it off with the wet hand. In this way the insulation is completed to the same diameter as the original.

In jointing gutta percha, the great point to guard against, is not to give it too much heat, if it is a little too hot it becomes oily and will not adhere.

The insulation having been thus completed, any outer protecting covering of wire, hemp, &c., should be laid on and secured which completes the operation.

In the case of an indian-rubber cable the following method is recommended.

Permanent indian-rubber joint. Before the portions of the conductor are soldered together, warm the two ends of the indian-rubber insulation and taper them off with a pair of scissors. After the joint is soldered and cleaned off in the manner already described, a little indian-rubber solution is rubbed on the small ends of the taper of the insulation and a layer of rubber compound tape, is wound round spirally and tightly, on the copper core, this compound tape is $\frac{3}{8}''$ wide; next a layer of indian-rubber tape, (not compound) $\frac{3}{8}''$ wide, is applied, then a thin layer of indian-rubber solution, followed by another layer of indian-rubber. Continue the alternate layers of rubber and solution until the joint approaches nearly to the diameter of the original core, and finish off with one layer $\frac{3}{8}''$ wide, commencing and finishing $1\frac{1}{2}''$ on each side of the joint. These layers must be each laid on very tightly and regularly.

When required, any outer protecting covering must be put on as before.

Permanent indian-rubber joint on gutta percha cable. In some cases it may become necessary to insulate a gutta percha cable with indian-rubber, and for this purpose the following method is recommended.

First apply a coating of indian-rubber compound (strip), then warm the gutta percha and taper it over the compound layer, then spread a thin layer of indian-rubber solution on the gutta percha, next apply a layer of indian-rubber $\frac{3}{8}''$ wide, followed by a thin layer of indian-rubber solution. Continue the layers until the insulation becomes nearly of the same diameter as the original core. Finish off with one layer $\frac{1}{2}''$ wide, commencing and ending $1\frac{1}{2}''$ on each side of the joint.

In making insulated joints, moisture, grease and dirt should be scrupulously avoided. So much stress is laid upon these points, that the manufacturers of submarine cables only employ men with very clean and naturally dry hands at such work.

Temporary insulated joints.

For temporary purposes, that is to say when a charge is to be fired immediately after immersion, it is unnecessary to make a permanent joint such as that described. For this purpose an ordinary piece of vulcanized indian-rubber tubing, passed over the naked ends of the conducting wires from the extremities of the two cables to be connected, which have been previously joined together and if necessary soldered, answers the purpose very well.

Indian-rubber tube joint.

To prepare this joint, about 1·5″ of the copper conductor of each of the insulated wires, which are to be connected together, are laid bare and thoroughly cleaned. A piece of vulcanized indian-rubber tubing *a*, *Plate* XXXVI., *Fig.* 2, about four inches in length, is then slipped over one of the insulated wires. The two clean and bright ends of the wires are then spliced or twisted together, as shown at *b*, care being taken to bend the extremities quite flat, so that they may not be liable to puncture the indian-rubber used for rendering the joint watertight. When the wires have been joined, the tubing is brought forward, so as to overlap the junction by about 2 inches, and is secured at each end upon the insulated wire by several laps of string *c*, *c*, tightly bound round. In order to relieve the junction from any direct strain, it is formed into a loop by tying together the insulated wires, at a distance of a few inches from the point where the junction is made, as shown in *Fig.* 3.

The insulation covered by the indian-rubber tube should be well greased, before the latter is pulled over it and tied. In doing this, care must be taken to prevent the grease penetrating to the metallic joint, and thus impeding the electrical circuit. The grease is intended simply as an additional precaution against leakage of water.

A very important matter to be attended to in making a joint, whether of a permanent or temporary nature, is that the metallic ends should be perfectly clean, that there should be no oxide or impurity, which would tend to increase the resistance to the passage of the current. To ensure this they should be well rubbed with emery paper just before the joint is made.

Moisture to be carefully excluded.

In making this or indeed any joint for submarine use, the great object is to exclude the very smallest ingress of water or even moisture, which would at once afford a path for the current and cause a loss or, as it is termed, a leak in the cable: if therefore there is any external hemp or other covering, through which moisture might percolate in ever so small a degree, it must be carefully removed, so that the indian-rubber tubing may come in direct contact with the insulation at the points where it is tied.

Care must also be taken to make the whole very dry, at the moment when the joint is made.

Nicoll's metallic joint.

A very ingenious mode of making the wire portion of the joint, has been invented by Donald Nicoll, Esq., of Kilburn. His idea suggested itself in connection with his own system of underground telegraph wires, but it is equally applicable to the formation of joints of the nature required for submarine work and is very simple. He first prepares the extremity of one of the conducting wires by forming it, by means of a very neat and ingenious little instrument, into a spiral twist, *Plate* XXXVII., *Fig.* 1, and the corresponding extremity of the cable to be connected being left straight, it is slipped in, the whole placed on a small anvil and, by a single blow of a hammer, pressed so closely together that soldering is almost unnecessary, while the joint is rendered capable of standing a considerable tensile strain.

Advantages and disadvantages of indian-rubber tube joint.

The great advantage of a joint insulated with this indian-rubber tubing, is the facility with which it can be made at any time and under any circumstances: it is also very economical. The chief danger to it is the chance of a projecting end of a wire perforating the indian-rubber, and causing a leak, though which a loss of current would take place; care must therefore be taken to prevent such an accident. One mode in which the chance of such a contingency may be reduced, is by lashing pieces of wood on, over the joint, outside the indian-rubber tubing, to prevent any bending at that particular point. Under Mr. Nicoll's system no projecting ends are left in making the joint, and the chance of a perforation is thus reduced to a minimum.

Indian-rubber joint approved for service.

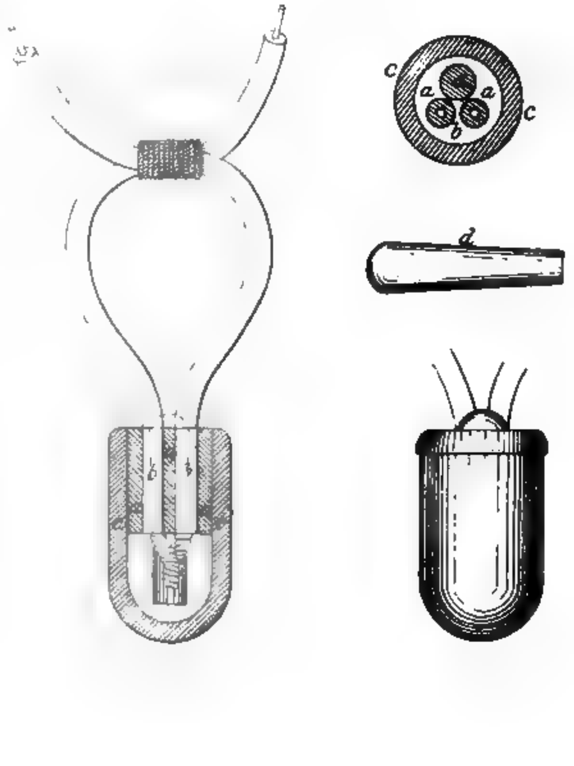
A joint, insulated with indian-rubber and protected by indian-rubber tubing, has been approved for submarine mining service. This joint is made in the following manner:—first strip the insulation off about $1\frac{1}{2}$ inches of the metallic conductor of each of the cables to be connected, taking care not to cut or injure the wires during the process. The bare wire extremities of the conductors should then be cleaned very carefully with emery paper, and all felt or other fibrous covering, scrupulously removed from about one inch of the insulation of the core, which latter should be tapered off towards the metallic conductor. About 3 inches of vulcanized indian-rubber tubing, should then be pulled over the extremity of one of the cables to be connected: this indian-rubber tubing is $\frac{3}{8}$ inches in internal diameter, a size which slips easily over the insulation of the core, and yet not so large as to hang loosely after it has been whipped down upon it with twine. This done, the extremities of the metallic conductors of the two cables are next joined together, by a German joint, and soldered: in making this joint, care must be used to prevent any projection of the wire ends, which might subsequently penetrate the indian-rubber tape and tubing, used to form the insulation. After soldering, the joint should be carefully cleaned and dried, the

PLATE XXXVII.

INSULATED JOINTS.

Fig. 1.

Fig. 2.



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B Butler, Corpl R E

latter being very necessary for the reasons already specified. Then proceed to wind on the indian-rubber tape, after applying a little indian-rubber solution, in the manner described at page 138 for the formation of an indian-rubber joint: in winding the indian-rubber tape on, it should be stretched so as to reduce its thickness to about half what it would be in its ordinary state. The insulation having been made up to the same diameter as that of of the original core, the indian-rubber tubing is pulled over the joint and firmly whipped down with strong double twine at each end. This joint has been very carefully tested for a considerable time, during our submarine mining operations at the Nore and elsewhere, and may be pronounced thoroughly reliable and sufficiently good, as far as insulation is concerned, for every purpose connected with this work, for which it may be required. The ordinary indian-rubber tube joint, described at page 139, should only be used where the charge is to be fired soon after immersion, as for example in submarine blasting operations: the joint approved for service is of a much more permanent character, and will remain efficient, if well made, for months after submergence.

Dent's bottle joint.

Another very good temporary joint, which may be very rapidly made, is that invented by Mr. Dent, of the Chemical Department, Royal Arsenal, Woolwich.

It consists of two parts, viz., a cylinder or plug of vulcanized indian-rubber *a*, about 1″ in length, and the same in diameter, (through which three holes, of sufficient size to admit the two insulated wires *b b*, *Plate* XXXVII., *Fig.* 2, and a tapering cylinder of wood *d*, have been bored by means of a red hot wire); and a stout glass tube *c*, *c*, about 1″ in diameter and 1¾″ in length, sealed at one end.

This joint is employed as follows:—Each insulated wire is passed through one of the holes in the vulcanized indian-rubber cylinder, and the cleaned bare ends of the metal wires are then twisted together and cut off short. If tape covered wire is used, the tape must be previously removed from about three inches of each wire. Into the third hole of the cylinder is loosely inserted a tapering plug of hard wood, *d*, about ⅜″ in diameter at the larger end, and 2 inches in length. The cylinder, with the wires and plug, is then firmly pressed into the glass tube, and the wooden plug is afterwards pushed into the hole as tightly as possible, as shown in *Fig.* 2, which has the effect of forcing the indian-rubber against the sides of the glass tube and around the insulated wires. It is important that the indian-rubber cylinder should fit tightly into the glass tube, and that the perforations, made to receive the wires, be not larger than absolutely necessary. A very small quantity of grease applied to the surfaces of the insulation of the wires, the plug, and the cylinder, will greatly facilitate the fitting up of the joint, and improve its efficiency.

Advantages and disadvantages of Dent's bottle joint.

This joint is extremely simple and economical, and is easily made. A joint made on this principle, was severely tried by being kept under a pressure of 18ft. of water, and tested at intervals with a reflecting galvanometer, under which treatment no appreciable loss of insulation was indicated during a period of 10 days. At the end of this time the glass cup was found broken, as if forced outwards by pressure from the swelling of the plug or wedge, while it remained submerged. It proved itself however an excellent joint as regards insulation. One of its defects is its inability to stand a tensile strain, in order to decrease the chance of which, as much as possible, the insulated wire connnections are tied together as shown in *Fig.* 2. Another is the chance of the breakage of the glass by a blow, to obviate which the glass cup is covered with an indian-rubber cap; it is however easy to arrange it in such a manner, that it may not be subjected to either of these contingencies. Another defect, above referred to, is the danger of breaking the glass, by pressure exerted from the inside, in consequence of the swelling of the wooden plug after immersion in water. In order to obviate it, the plug should be made of box or some other very close-grained wood.

Glover's joint.

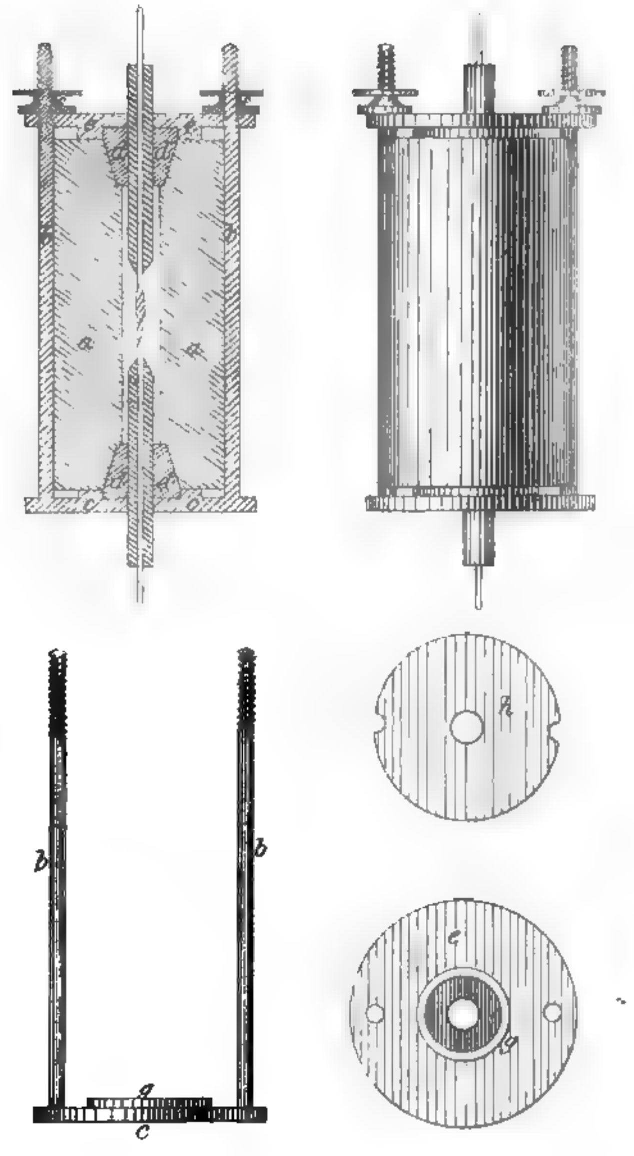
Another, and much more elaborate joint, is that invented by Corpl. Glover, R.E. It consists of an ebonite cylinder *a*, *Plate* XXXVIII., fitted with two grooves to receive the uprights *b*, *b* of a brass disc *c*, which forms one end of the apparatus. This ebonite cylinder is bored through the centre, to admit the wires to be joined, with their insulation, and the diameter of the bore is expanded, at each extremity, into a conical hollow to receive two similarly shaped plugs *d*, *d*, of vulcanite, which latter pass over the insulation of the wires and fit accurately into the cavities left for them; *h* shows a horizontal and *a* a vertical section through the ebonite cylinder. A brass disc *e*, similar to *c*, but with holes to receive the brass uprights of the latter, is placed over the top of the ebonite cylinder and is held firmly on by screws *f*, *f*, passing on to the uprights. A small projecting rim *g*, on the lower disc, *c*, and a similar arrangement on the upper one *e*, keep the vulcanite plugs from being forced out laterally when pressure is applied. A metallic connection having been established, by twisting the conducting wires together, the outer protecting covering having, as before, been carefully reremoved, the bare wire is drawn into the centre of the ebonite cylinder, the screws *f*, *f* are tightened and the vulcanite plugs are driven forcibly into their respective cavities, making the whole watertight. A little grease carefully applied to the insulating material at the points of pressure, will in this, as in other similar cases, improve the insulation of the joint.

Defects of Glover's joint.

The defects of this joint are its high cost and the uneven bearing given by the two screws used in tightening up; this latter might however be obviated by the employment of three screws,

PLATE XXXVIII.

GLOVER'S JOINT.



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B Butler, Carpl R E

BEARDSLEE'S AND McEVOY'S JOINTS.

Fig.1.

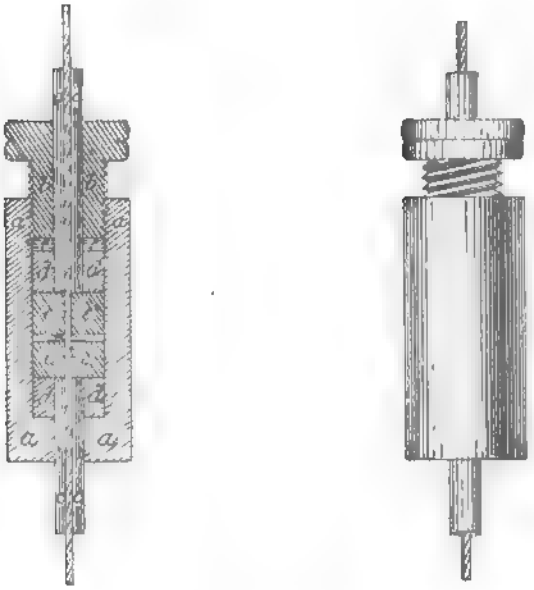
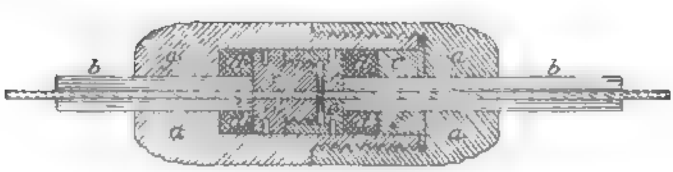


Fig 2.



Lithographed at the S M E Chatham. B Butler Corpl. R.E.

in a triangle, instead of two, by which all side motion, after the process of tightening up, would be obviated.

Beardslee's joint.

Another joint is that said to have been invented by Mr. Beardslee, of New York, but bearing the name of Goodyear's patent, on a specimen left at Chatham by him. It consists of an ebonite cylinder *a*, *Plate* XXXIX., *Fig.* 1, with closed ends, one a fixture and the other fitting the cylinder with a screw *b*. Each end has a perforation, of sufficient size to admit the insulated wires *c c*, which are to be connected. The bare extremities of the wires having been cleaned to the extent of about $\frac{3}{8}''$, each one is passed through one of the perforations in the joint, as well as through a disc of vulcanized indian-rubber, *d d*, about $\frac{3}{8}''$ thick, and one of metal *e e*, $\frac{1}{4}''$ thick. The bare extremities of each conductor are secured by spreading them out upon the metal discs, and these are then brought into close contact, in the interior of the ebonite cylinder, by screwing up the moveable end thereof as tightly as possible. *f* is a metal washer to prevent twisting.

Specially applicable to a strand conductor.

This joint is specially applicable to a strand conductor, composed of a number of fine wires, which may be separated and spread over the metal discs so as to ensure good contact.

The usual precautions, as to the removal of any outer protecting covering and greasing the insulation, must be borne in mind in forming this joint.

It is particularly necessary, in employing this joint, to guard against direct strain being thrown upon the wire extremities which are enclosed, as they would be even more liable to be drawn out of the cylinder, in which they are rigidly fixed, than in the case of other joints; the electrical connection, in this case, being formed by the simple contact of the two metal discs and not by twisting the wires together. The wires should therefore be firmly braced together at a short distance from the point of junction, as shown in *Plate* XXXVII., *Fig.* 2.

Defects of Beardslee's joint.

The defects of this joint are its inability to stand a tensile strain, which would tend to draw out the wires, or so far separate the metal discs, on which the wires are spread out, as to break the metallic contact and thus interrupt the current, and that the wires to be connected cannot be soldered.

Mc Evoy's joint.

Captain Mc Evoy, late of the Confederate Torpedo Service, now of the London Ordnance Works, Bear Lane, Southwark, has designed a joint, which is an improvement upon Beardslee's. It is adapted for joining strand conductors. Instead of the two metal discs used by Beardslee, Mc Evoy employs two brass pieces, on which the wires of the strand conductor are spread out, while the two brass pieces are made to screw tightly one into the other, in this way a metallic connection is secured and the two sections cannot be drawn away from each other as in Beardslee's. Over the two brass pieces and round the insulation of the cores, come the two indian-rubber cylinders, as in Beardslee's apparatus:

one of these indian-rubber cylinders rests in the end of one of the sections of the outer part of the joint, while over the other he places a washer, projecting beyond the threads of the screw forming the coupling. The other portion of the outside of the joint, comes down on this washer when the apparatus is screwed up, and by this means all tendency to twist is avoided. *Fig.* 2, *Plate* XXXIX. shows this joint in section. *a*, *a* are the coupling screws and the two parts of the outer portion: *b*, *b* the two insulated wires to be connected: *c* the washer, to prevent the tendency to twist in screwing the apparatus home: *d*, *d* the indian-rubber cylinders; and *e*, *e* the brass pieces used for connecting the conducting wires in the centre. In this form of apparatus, the outside connecting pieces *a*, *a*, may be made of brass, if the brass connecting pieces *e*, *e* be covered by an insulating tube: by this means greater strength is secured, as compared with Beardslee's apparatus, which is made of ebonite.

Mathieson's joint.

Another joint is that invented by Qr.-Mr. Sergt. Mathieson, R.E. It consists of two ebonite cylinders, *a*, *a*, *Plate* XL., perforated to receive the cables to be connected, the opening at the outer extremities being just large enough to admit the insulation of the wire to pass freely, while the inside is larger, thus forming shoulders, against which thick perforated vulcanite rings *b*, *b*, encircling the insulation, are placed. Within these cylinders is an ebonite tube, with wedge formed ends in contact with the vulcanite rings, within which the wire connection should be placed. The centre of the tube *c* is of a square section, and fits into a hollow of similar form in the cylinders *a*, *a*, the ends of the tube are of circular section; the object of the square centre is to prevent the wires, to be connected, being twisted round and round during the process of tightening up, as any torsion of this nature would be liable to disarrange the metallic connection or to injure the insulation. A coupling screw, *d*, with a shoulder, to catch a corresponding shoulder on one of the ebonite cylinders, and a corresponding screw on the other, completes the arrangement.

Portions of the coupling screw and one of the ebonite cylinders are made of hexagonal form, to fit a couple of spanners to be used in tightening up the apparatus, when greater force than that which can be applied with the hands is necessary. It is easily seen how, by tightening up the coupling screw, the two ebonite cylinders may be drawn together and the internal tube forced upon the vulcanite discs, making the whole watertight.

To make a joint.

To make an insulated joint with this apparatus, the coupling *d* is unscrewed as far as possible, without separating the two parts *a a*, and a little grease is applied to the threads of the screw; the whole apparatus is then slipped bodily on to one of the insulated cables to be connected; the insulation of each cable is then carefully tapered off to a blunt point and rubbed with a little grease, taking

MATHIESON'S JOINT.

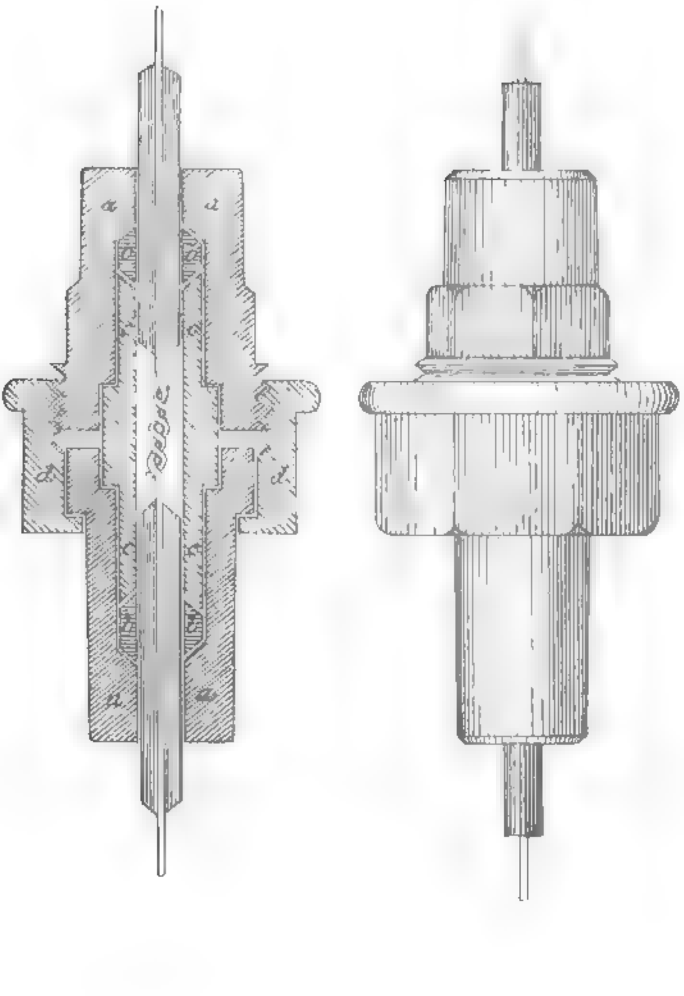


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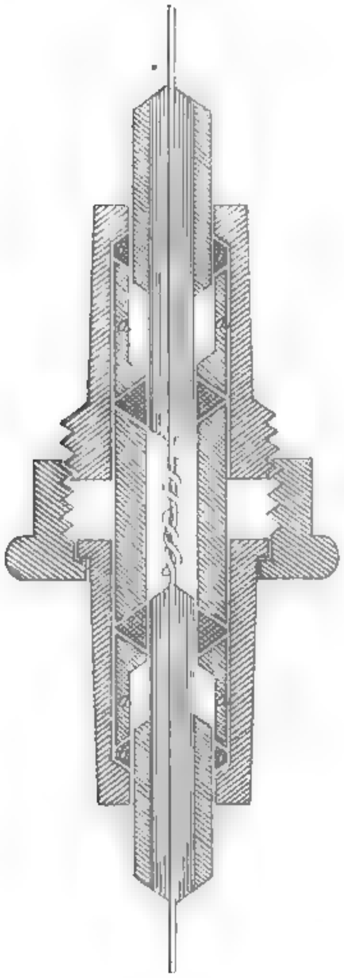
PLATE XLI.

MATHIESON'S JOINT.
FOR ARMOURED CABLE.



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care that this latter does not extend to the metallic conductor. The extremities of the metallic conductors, having been carefully cleaned, are next twisted together so as to leave as short a length of naked wire as possible, care being taken that the diameter of the two wires, when twisted together, does not exceed that of the insulation. The exposed metallic joint is next drawn back into the centre of the connector, which is then screwed tightly up with a spanner, and the indian-rubber packing so firmly wedged round the insulation, as to exclude damp most effectuallyfrom the bare conducting wire in its centre.

The same apparatus may be used more than once.

If the connector be unscrewed and the ends of the wire carefully drawn out, the same apparatus may be used any number of times, provided it has not been injured by the explosion of a mine. If the inside be wetted it must not be used again till thoroughly dried; special care is necessary if it has been accidentally wetted with sea water, the latter being a better conductor of electricity than fresh water.

When the cable is covered with an outer protection of tape, hemp, or any similar substance, it is necessary to remove this carefully from the vicinity of the joint, as the damp would penetrate through the fibres were it allowed to remain.

Experiment to test insulation.

In order to test the efficiency of this apparatus, a piece of cable, which had previously been tested for insulation and found good, was cut into *nine* pieces, and joints made at the cuts with Mathieson's joint, thus forming *eight* points through which the current might leak. This was sunk to the bottom of the river Medway, a depth of 36 feet, and tested, from day to day, for a period of more than two months, with 48 Daniell's cells and an astatic galvanometer, without showing any indication of leakage of current.

This joint possesses considerable tensile strength, but where it is likely to be submitted to any considerable strain, it is nevertheless a good precaution to form a loop in the cable, as recommended for those previously described and shown in *Plate* XXXVII., *Fig.* 2.

Mathieson's joint for cable with wire protecting covering.

When an insulated cable has an outer protecting covering of wire, a modification of Mathieson's joint may be used. This is shown in section in *Plate* XLI; a simple addition, in the shape of two ebonite tubes *a a*, made to pass easily over the outer protecting covering, with indian-rubber cylinders *b b*, also fitting over the same, in addition to those in contact with the ebonite tube covering the metallic joint of the conducting wires, is all that is necessary. It is easily seen how, by simply drawing the parts of the apparatus together, by means of the coupling screw, everything may be made watertight and consequently insulated as before. In making a joint on a cable with an outer protecting covering of wire, this latter must necessarily be removed, and a weak place, at which the cable would bend easily, would be

formed. The joint described, by gripping the outer covering beyond the actual point of connection, prevents any such bending with the danger inseparable from it of piercing the insulation by a projecting wire.

These joints must be made to fit the insulation of the cables they are intended to connect, with a certain amount of accuracy. They must be sufficiently loose to slip easily over it, before being screwed up, and the limit, within which a joint made for one size of cable may be used for a smaller one, is dependent upon the extent to which the indian-rubber cylinders may be compressed, so as to fill up the vacant space and make the joint watertight.

When there is no iron in contact, to be damaged by the electrical action set up by the sea water, the coupling screw and outer portions of this joint may be made of gun metal, which gives greater strength than ebonite.

Advantages of Mathieson's joint.

Mathieson's is decidedly the best of all the temporary joints described, possessing, as it does, excellent insulating qualities, great facilities for making or detaching a connection between two cables in a short space of time, and being capable of standing a considerable tensile strain. In many situations it may conveniently be used to supply the place of a permanent insulated joint, to which, as far as general insulating qualities are concerned, it is quite equal, and to which, where facilities for examination are required, it is superior.

Experiments to test temporary joints.

All the temporary joints above described were tested for insulation, similarly to Dent's, (see page 142), and all stood the test, which was a very severe one, remarkably well. Mathieson's was again more severely tested, as already described, with very satisfactory results.

Special, indian-rubber tubing joint adopted for service.

After numerous experiments with Mathieson's temporary joints, as well as with the special indian-rubber joint described at page 140, it has been decided to adopt the latter for submarine mining service. It can be made with sufficient rapidity, and has proved itself quite efficient for all purposes required: it is, moreover, cheaper and occupies less space than any of Mathieson's joints. A description of these latter, as well as of those designed by Beardslee and Glover, is given, in order to show the course of experiments by which our latest decisions have been arrived at. These temporary joints are, moreover, extremely ingenious, and a knowledge of their construction and application is necessary, and may prove useful under certain circumstances. When the service, indian-rubber tape and tubing joint is employed, the connecting boxes, shown in *Figs.* 1 and 3, *Plate* XXXII, are used for joining two lengths of insulated, protected conductor. These are simpler and more economical than Mathieson's joint for armoured electric cables.

CHAPTER IX.

Storage of Apparatus, Submerging Mines, &c.

We now come to the mode of storing the cases, cables, sinkers, electrical apparatus, and explosives: to the mode of loading and connecting up the charges, and of placing the mines in such a position that they shall be most effective, and at the same time so disposed that the explosion of one shall not injure the cables, circuit closers, &c., in its vicinity: and finally to the mode of introducing the electric cables and their connections into a fort, and to the arrangements of the testing tables and apparatus.

Austrian store for submarine mines.

One of the most complete establishments, for the storage of apparatus required for a system of defence by submarine mines, is that of the Austrian Government at Pola, where everything of this nature, connected with the defence of the ports of the Istrian Peninsula, has been arranged in a very compact and convenient form. In this establishment, due regard has been paid to the preservation of all stores and apparatus of a perishable nature, so as to secure them to the utmost extent from those agencies which induce decay. In offering the following remarks on storage, the general arrangements of the Pola establishment have been taken as a guide.

Position of a store for materials & apparatus.

Where a moderately large quantity of material and apparatus is required for a system of defence by submarine mines, the store in which it is placed should be as close as possible to the water, due regard being paid to its safety from bombardment by an enemy's attacking forces. It should be provided with a wharf, alongside which vessels drawing 7 feet of water could lie safely at all times of tide. A tram-way should communicate from the store to the wharf, in such a manner as to suit the positions of three cranes, provided for loading and unloading vessels. One of these cranes should be capable of lifting a weight of 5 tons, while the other two should lift a weight of 2 tons each.

Storage of cases.

It is of considerable importance, that the cases for submarine mines should be well protected from the sun and from the action of the weather. They should therefore be stored in a long shed,

with side walls, down the centre of which should run the tram-way communicating with the wharf. The most convenient method of stowing the cases would be in two rows, one on each side of the tram-way and each row two deep, the ends of the cases being directed towards the tram-way. Each row might be about three cases high, and a space should be left between the outer walls and the rows of cases for purposes of inspection, to facilitate which the loading holes should always be turned outwards.

Storage of circuit closers.

The circuit closers consist of two parts, the wooden jackets and the metal domes with internal apparatus. These should be stored separately: the wooden jackets in rows, piled one above the other, with plenty of ventilation, and the domes and internal mechanism, each in a wooden box, specially fitted to contain the whole of this portion of the apparatus, complete. Both wooden jackets and domes with apparatus should be kept under cover. When the wooden jackets are placed in store, they should not be painted or tarred, in this way they would be allowed to season.

Storage of 100lb. electro-contact mines.

Similar rules should be observed in the storage of the 100lb. electro-contact mines, as for the circuit closers. The wooden jackets should be stored separately, and the sheet iron cases in piles, conveniently accessible for the purposes of inspection. Before the wooden jackets of the electro-contact mines, or of the circuit closers, are put in the water, they should be well tarred and, if possible, afterwards painted of some invisible colour, such as French grey. The tarring is a necessity, to keep the water from penetrating into the pores of the wood, and it is doubtful whether painting over the tar would be effective.

Storage of electric cables.

Electric cables, when insulated with gutta percha, must always be stored under water and in the dark; when insulated with indian-rubber they may be stored either dry or wet. In this latter case, care must be taken to keep them always dry or always wet, as any alternation of these conditions would be liable to produce rot in the di-electric, as well as in the hemp and other protecting coverings. When stored under water, tanks must be provided, which may either be constructed of brick in cement or of iron. When electric cable is supplied in bulk, it would generally be most convenient to store it under water: such an arrangement affords facilities for testing which are of great advantage. When electric cable is supplied on wooden drums, it would generally be most convenient to store it dry. The dimensions of the tanks required to hold any given length of electric cable, of the size adopted for service, in a convenient form, would be somewhat as follows:—

For 8 miles of single cable, a diameter of 11 feet and height of 3 ft. 4 in., with a cylindrical core, similar to that of a drum, on which the cable is wound, in the centre of 3 feet in diameter.

For 16 miles of single cable, a diameter of 13 feet and height of 5 feet, with a core of three feet in diameter, as before.

For 3 miles of multiple cable, a diameter of 10 feet and height of 3 ft. 9in., with a core of 4 ft. in diameter.

For 6 miles of multiple cable, a diameter of 12 feet and height of 4 ft. 6in., with a core of 4 feet in diameter.

The tank containing the cables should be accessible by the tram-way, and sufficiently near the testing room to enable connections to be made with the cables with facility. A space should also be provided, close to the tanks, on which the winding apparatus, used for moving the cable into and out of the tanks, may be conveniently worked.

Storage of Sinkers. The cast iron sinkers, of the several forms approved for submarine mining service, may be stored in the open air, in a position easily accessible by the tram-way. The most convenient surface on which to lay them would be a well drained stone pavement. A crane on one of the trucks supplied for the tram-way, would be very convenient for shifting some of the heavier weights to be moved.

Storage of electrical apparatus, &c. The electrical apparatus for testing and working a system of submarine mines, including the batteries, should be stored in a room partitioned off at one end of the shed. Each set of articles of the same kind should be placed together, and it would be convenient to arrange the whole on a series of numbered shelves, easily accessible, the heaviest weights being placed below.

Office or Storeman's room. An office, or storeman's room, should be provided for each establishment, to contain all books and documents connected with the charge of the stores, or with the plans for the defence of the port for which the store is provided, these latter being, of course, kept under lock and key.

Testing room. An electrical testing room, about 20 feet square, provided with the necessary instruments and apparatus for making all the electrical tests required, should form part of the establishment. The testing room, storeman's office, and store for electrical apparatus and small stores, might be placed together at one end of the building, while the tram-way might enter at the other, and run through the centre, as far as the space allotted to the heavy stores extended: though such an arrangement would be convenient, it would of course be necessary to modify it, to suit the particular shape of any space available or other local circumstances.

Workshop. A workshop, of sufficient size to contain a small smithy, space for tinman's work, and a carpenter's bench, should be provided.

Shifting room. A shifting room, in which the cases would be loaded, and other work entailing the manipulation of explosives would be performed, should form a part of the establishment. This room should be a small separate building, somewhat apart from the main store.

Storage of gun-cotton and other explosives. Pending the decision of the Committee now engaged in the investigation of the subject of explosives, no definite rules can be laid down for the storage of gun-cotton, as to the nature of the

building suitable for such a purpose, or as to the question of storage in a wet or dry state. It is probable, however, that where the simple storage of a large mass of gun-cotton is the object to be attained, without regard to its safety from the fire of an enemy, slightly constructed buildings would be preferable for such a purpose: and till we know a little more about its qualifications, it would seem desirable, as a matter of precaution, to store it wet, and in wooden boxes, as slightly constructed as is consistent with safe transport and handling. Experiments have proved that, in this state, it is at least moderately safe. One thing must be borne in mind, namely, that however it may be stored, it should be treated as an explosive and not as a simply inflammable substance. Gun-cotton being the explosive selected for submarine mining service, but little need be said concerning the storage of other explosives, such as dynamite, lithofracteur, &c., into the composition of which nitro-glycerine enters: it is only necessary to remark, that such substances should be guarded with extreme care, and every precaution taken to prevent accidents. They should be treated strictly as explosives, however much may be said about their comparative safety and other useful qualities for storage. Gunpowder should, of course, be kept in any ordinary magazine, and it would be desirable to store any great mass of explosive which may be required for service, at some little distance from the establishment containing the cases and electrical apparatus.

Storage of detonating fuzes.

Detonating fuzes should be stored apart from any explosive, and might be kept in any building, provided within the fortress, for stores of such a nature, and drawn out in small quantities, from time to time, as required.

Stores should be complete in all particulars.

In the Austrian store at Pola, everything required for submarine mining purposes, down to the most minute detail, is kept at hand and ready for instant service. The whole establishment is under the charge of an officer of the Engineer Corps, who is also Instructor in Submarine Mining. There is a very great advantage in this arrangement: everything required is at once procurable, the stores are under the charge of a competent officer, who is responsible for their being always in a serviceable condition, and who, from the tests employed and from the actual use made of the stores for instructional purposes, is able to say with confidence whether they are efficient in themselves and in good working order, and to suggest improvements which may occur to him in actual practice. Some arrangement of this sort is absolutely necessary to the efficiency of the system, wherever a depot of stores for submarine mining service may be placed.

Officers and men to be practised at intervals.

Apart from their original instruction at the School of Military Engineering at Chatham, it would be necessary to practise the Officers, N.-C. officers, and men employed, at frequent intervals, at all out-stations, so as to keep them efficient for service; and

the necessity for putting an officer in charge of the stores and apparatus, who is thoroughly acquainted with their construction and use, is so obvious as to need no comment.

Cases, circuit closers, and all apparatus to be tested before being connected up.

It is of considerable importance to ascertain, before loading and connecting up the charges, previous to placing them in position, that the cases and circuit closers are watertight and the fuzes, electric cables, &c. efficient and fit for service. The qualifications of all materials and apparatus, are carefully tested before they are placed in store, but it is always necessary to test them again, immediately before they are connected up for use, to see that they remain in good working order. Before being placed in store, the cases are always submitted to a test by hydraulic pressure; the sheet iron, of which the case is made, is however comparatively thin, and it is quite possible that, in the process of moving them from place to place, they may be slightly injured in such a way as to produce a small leak: hence the necessity for this further test. The same holds good as regards all stores and apparatus. The details of the different tests employed shall be described hereafter.

Loading the case.

When the case has been proved watertight, it is ready to be loaded. For this purpose, when gun-cotton is the explosive employed, it should be laid on its side and the gun-cotton discs packed, as closely as possible within it, by hand. In doing this, it is unnecessary, in the first instance, to distribute the gun-cotton discs: they may be simply taken out of the boxes in the packets in which they are arranged, and placed, in this form, in the bottom of the case. When the case is nearly full, it should be turned on its end, and the loading continued in such a manner as to provide a space for the introduction of the fuzes, with their priming and protecting zinc guard. As the loading approaches completion, the packets, in which the gun-cotton discs are stored, must be broken up, and single discs used to fill up the smaller spaces. In order that the correct weight of gun-cotton may be placed in each charge, the gross weight of the wooden boxes, when full, should be taken and the weight of the empty boxes subsequently deducted.

Loading with other explosives.

The mode of loading with gunpowder or any other explosive, must be suited to its nature. With gunpowder, or any granular substance, the operation would of course be very simple, as it would only be necessary to pour it in, taking care, during this operation, not to disturb the position of the fuzes, if the charge were of such a size as to necessitate their being introduced further into its mass, than is required in the case of gun-cotton fired by detonation. The cases should be loaded in the shifting room provided as a part of the store establishment. Cases should always be loaded, with the air inside them, as nearly as possible, at the same temperature as the water in which they are about to be immersed. The reason of this is that, after immersion, cold

Cases to be loaded at temperature of water.

condenses any moisture, which may be held in suspension in the air within them, when they are loaded.

Selection of fuzes.

After the case has been loaded, the next operation is the selection of the fuzes, two of which are employed in each charge. These should be of equal electrical resistance, and should be selected, as nearly as possible, of 15000 ohms each, when the submarine electric fuze, (No. 5 detonator, electric, Abel, submarine), is employed. This fuze should always be used for the 250lbs., 500lbs., and all charges, arranged with circuit closers, as shown in *Plates* XVI. and XVII, the platinum wire detonator being employed in connection with the electro-contact branch system. The mode of determining the resistance of these fuzes, by means of Wheatstone's bridge, and of testing them in other respects, shall be described hereafter. The fuzes should be connected together, as shown in *Fig.* 3, *Plate* XXXIV., in simple divided circuit: before they are connected together, they should be thoroughly waterproofed, by painting them and their connections carefully over with sealing wax varnish: great care should be observed in this operation, so as thoroughly to exclude the damp, already referred to as likely to be produced by condensation. After being connected, all the bare wire at the several junctions should be very carefully insulated, by means of indian-rubber tape and solution.

Connecting and water-proofing fuzes.

Tests of fuze plug.

The next operation is to test the fuze plug. The wire terminals, at both ends, are first tried with a galvanometer and small number of battery cells, to identify them, and they are marked E E and L L, earth and line, at each extremity, on the ebonite, for future reference. The wires should next be tested, to see that they are not in contact, within the apparatus, by connecting their outer terminals with two cells of a testing battery and a galvanometer, on which latter no deflection should occur when the construction is good: they should then be tested for continuity, by completing the metallic circuit across their inner terminals, the testing battery and galvanometer remaining in circuit with the outer terminals, as in the previous test: under these circumstances, the full deflection, due to the battery current on short circuit, should be observed on the galvanometer, when the continuity is good. The wires of the fuze plug should finally be tested for insulation, by immersing the whole apparatus in a vessel containing acidulated water, taking care to keep the bare wire terminals dry, and testing with 100 cells of a Daniell or Leclanché battery and galvanometer in circuit: if good, no deflection should be observed. Before making this test, the fuze plug should be allowed to soak for some hours in the acidulated water, to allow the latter to penetrate into any imperfections or cracks in the insulating material. Should the waterproof composition become cracked at the inner end of the fuze plug, in consequence of the operations to which it is subjected during the

testing process, it should be smoothed over with a hot wire and neatly closed round the base of the protruding copper wires.

Attachment of earth plate.

The fuze plug having been proved to be efficient, the next operation is to connect it with the earth plate, fuzes, &c. The earth plate for the charge, consists of a rectangle of graphite, $2\frac{1}{2}$ inches by 3 inches and about $\frac{1}{8}$ inch thick. Two holes are bored in it, one large enough to take the insulated core of the earth (E) outer terminal of the fuze plug, the other of a size to admit the conductor only: these are passed through the holes and the latter carefully secured and soldered into its place, a good lump of solder being formed on each side of the carbon plate, in order to hold the wire firmly in its place; solder does not itself adhere well to carbon: all the exposed metal of the conductor, as well as the soldering, is then carefully coated over with pitch, to prevent contact with the sea water, with its consequent local electrical action. The earth plate is then carefully enclosed in canvas, to prevent its touching the iron of the case, which would interfere with its use for testing purposes. The fuze plug is next passed into the opening left for it in the iron disc of the mouth piece, a leather washer, well smeared with red lead, having been put in position, resting on the shoulder provided for its reception, the brass collar ring is slipped on, and the hexagonal union, with threads well greased, screwed up tightly with a spanner to make all watertight, as shewn in *Plate* VI., *Fig.* 1, and described at page 55. This done the apparatus may, for convenience, be put in a vice, with the insulated wire terminal and earth plate downwards, the vice gripping the iron disc of the mouth piece.

Attachment of fuzes, priming, and zinc guard.

The lower portion of the zinc guard is now slipped on to the ebonite fuze plug. The two fuzes, connected in simple divided circuit, are next attached to the inner terminals of the fuze plug in the following manner. One terminal of the fuzes is attached to the line (L) terminal of the fuze plug by means of a Britannia joint, a double copper wire of No. 22 B.W.G., 2 feet long, being used for binding:—one foot in length of this binding wire is employed in the binding itself, the remainder is led under the lower portion of the zinc cylinder (guard), twisted round and soldered to it:—the object of this connection is for testing purposes, as shall be hereafter described. This wire should be well coated with sealing wax varnish, to prevent the copper of which it is composed coming into contact with the water in the event of the charge becoming wet. Any such exposed copper entering into combination, would interfere with the testing, as shall be hereafter explained. The other terminal of the fuzes is connected to the inner earth (E) terminal of the fuze plug by a German joint:—both connections of the fuzes are soldered and insulated from each other by indian-rubber tape and solution, in the manner described at page 140, indian-rubber tubing being

however omitted in these particular joints. The priming disc of gun-cotton is now put on, the conical projections of the detonators being pushed into the holes left in it for their reception. Should no discs with the permanent holes be at hand, it would be necessary to perforate the discs used with a piece of wood, taking care that the conical projections shall fit tightly into the holes made. The top of the perforated zinc guard is now put on, and made fast by means of the bayonet socket joint:—the zinc guard not only protects the fuzes, with their connections and gun-cotton priming disc, from disturbance should the charge be packed at all loosely, but serves for the purpose of an electric test, indicative of the wet or dry condition of the charge, in a manner to be hereafter described.

Putting fuzes into charge.

The iron disc of the mouth piece, with the fuze plug, fuzes, &c., complete, is inserted into the charge, a washer or grummet, made of unravelled spun yarn, saturated with red lead, having been placed in position to receive it, within the channel of the mouth piece, and the whole is screwed firmly down by means of the screw collar with the hexagonal top, as shewn in *Fig.* 1, *Plate* VI., a spanner being employed for this purpose, making the whole perfectly watertight. The iron dome may then be put on, with screws just holding, as a temporary measure.

Adjustment of circuit closer.

No means for regulating the sensibility of the circuit closer, as regards the force of the blow required to set it in action, have yet been definitely decided on: for the present a provisional method, to be hereafter described in treating of the details of the circuit closer, has been adopted: by this method the springs and screws have been hitherto adjusted in a manner which has proved perfectly satisfactory, in the experiments which have now been carried on for many months at the Nore. The object to be attained, is to give the apparatus that amount of sensitiveness, which will ensure its acting effectively if struck by a ship, and yet preserve such an amount of rigidity as will enable it to stand the rocking motion of the sea, when subjected to the action of the waves, without completing the circuit.

Test of circuit closer for leakage.

The circuit closer should be tested, to ascertain whether it is watertight, in a similar manner to that described for the cases, viz:—to complete the whole of the connections of the dome with the base, base plug, &c., and sink it, without its wooden jacket, for 24 hours, at rather more than the depth at which it is subsequently to be immersed for service; opening and examining it carefully after it has been taken up, to see that it remains perfectly dry. This examination may be made, by simply removing the cap at the top of the dome, without disturbing the other connections. It is convenient to make the whole complete, as for service, before making this test by immersion: if found good the connections need not afterwards be disturbed.

Connections

The base plug of the circuit closer should be tested in precisely

the same manner as the ebonite fuze plug, and its terminals marked E, E and L, L, to indicate earth and line, as already described. It is then put in its place, in the base piece, and screwed up with washers, &c., to make it perfectly watertight. For certain tests, to be hereafter described, a resistance coil of 1000 ohms, in the form of a bobbin, has been introduced into the circuit closer; this coil is so arranged, as to produce the effect of a permanent leak, of 1000 ohms resistance, between the circuit closer connections and the line wire. The inner earth wire (E) of the base plug, is first connected to one of the screws on the upper surface of the block, and the three screws, at this part of the apparatus, are joined together by short connecting copper wires. One terminal of the 1000 ohms resistance coil, is connected to the earth wire (E) terminal, within the apparatus; the line wire (L) terminal is connected to a screw on the side of the insulated disc, and the other terminal of the 1000 ohms coil, is connected to the line (L) terminal, just below its attachment to the screw on the disc. The connections of the coil with the terminals should then be very carefully insulated, with indian-rubber tape and solution, to prevent any chance of short circuiting through those points. If this insulation is well executed, the apparatus will work even after a considerable quantity of water may have leaked into it, it is necessary, therefore, to be particular in this respect. The bobbin itself should then be firmly attached to one of the pillars of the apparatus: this must be done carefully, so as to preclude the smallest movement, as a continuance of even the slightest motion, as produced by the action of the sea, has been found to act prejudicially, and even, in time, to break the connections of the fine wires of the coil. These connections are used entirely for testing purposes: for signalling, the earth connection is made through the body of the instrument, which is put in metallic connection with the screws attached to the top of the springs for that purpose. This is done by means of a bare copper wire, connected to the screw at the top of one of the springs, and passing thence round one of the brass pillars, to which it is firmly lashed, and on to a screw in the base of the metallic portion of the apparatus. The screws at the top of the springs are all connected together by bare copper wire. The whole of the connections having been made, the dome is next screwed firmly down over the apparatus, against the washer arranged for its reception in the base piece, so as to make everything watertight.

of circuit closer.

Attachment of 1000 ohms testing coil.

To form the earth connection, a piece of the unprotected cable, *Plate* XXX., *Fig.* 1, used for telegraphic purposes, five feet long, is provided. The perforated metal plate in the side of the wooden jacket having been taken out, one end of this piece of insulated cable is passed upwards through the chamber in the top. The earth plate, which consists of a piece of zinc $3\frac{1}{2}$ inches

Earth connection of circuit closer

square and ¼ inch thick, is then attached to this insulated conductor, the wire, being passed through holes made in the earth plate, (a large hole receiving the insulated core and a small hole the conductor only), and the point of contact carefully soldered, the places where the bare metallic conductor and soldering are exposed, being subsequently well covered with pitch to prevent local electrical action. The earth plate and connecting wire are then so disposed in the vertical chamber, with a loop of the latter uppermost, that the former may be easily withdrawn at any time for examination. The earth plate in this case, being in a wooden chamber, it is not necessary to cover it with canvas, this precaution would only be required, in the event of its being likely to come in contact with any metallic surface. The other end of the insulated earth connection is then passed downwards, through the hole provided for it in the wooden jacket and through the opening for its passage in the base plate, and it is connected to the earth terminal (E) of the base plug, by means of an indian-rubber tape and tubing joint, as described at page 140, and the dome slipped into its place, within the wooden jacket. The perforated metal plate is then replaced in position in the side of the apparatus.

Attachment of circuit closer cable. The electric cable, to connect the circuit closer with the charge, is next cut to the required length, 18 inches being provided for jointing, and from 3 to 6 feet for slack, above the length required to connect it with the charge. One end is passed from the outside through the hole in the centre of the wooden base plug, now detached from the rest of the apparatus for this purpose. About 9 inches of this end of the insulated core, should be stripped of its armouring, and the ends of the projecting wires turned back and well served round with spun yarn, to form a turk's head. The cable is then securely gripped, by means of the clip outside the base piece. The turk's head is chiefly intended, to prevent the exposed ends of the wire armouring from projecting in such a manner as to injure the insulation of the cable, and must not be relied on to take any strain on the cable, which is all received at the point where it is gripped by the clips outside the base piece, and in order to ensure firmness, a padding of spun yarn must be put on round the cable at this point when required. This form of finish to the cable would, however, take the first strain of a severe pull and, in the event of the clips slipping, would be of great service in preventing the strain coming on the weaker portion at the insulated joint. The core of the electric cable is then connected to the outer line (L) terminal of the base plug by an indian-rubber tape and tubing joint, as described at page 140. The dome complete should now be attached to the wooden base piece, by means of the pillar bolts, passed through and screwed up tightly by the nuts provided for this purpose. The whole should then be pushed into the wooden

jacket, and fixed therein by means of the iron rods and top and bottom iron plates, and similarly secured by nuts as before. The core of the other extremity of the electric cable, attached to the circuit closer, should then be stripped of its protecting armouring for about 9 inches, and a turk's head should be formed as before: it should then be formed into a hank of convenient size, tied round with spun yarn at one or two places, and deposited with the circuit closer.

Apparatus for mooring circuit closer.

The attachment chains should next be inserted into the shackles at the base of the circuit closer, with a spare shackle in the central ring. The Bessemer steel wire mooring rope should next be cut to the required length, and prepared with an iron thimble at each end, round which the wire rope should be passed and hammered, to make it fit as closely as possible to the thimble, it should then be very firmly bound below the latter, by means of spun yarn, or, still better, iron wire. One end should then be attached to the central ring of the attachment chains, by means of the shackle provided in the latter, and it may finally be formed into a hank, like the electric cable, and deposited therewith. The circuit closer complete is then ready for attachment to the mine.

Mooring 500 lbs. buoyant mine.

The mode of mooring a 500lbs. gun-cotton buoyant mine is shown in *Plate* XVI., page 75. The case, having been loaded and fitted with its fuzes, &c., as already described, is next provided with its attachment chains at top and bottom, by shackling them into the lugs provided for that purpose. The centre ring of the upper attachment chains is furnished with a shackle, to form its connection with the Bessemer steel, wire, mooring rope of the circuit closer; and a $\frac{3}{8}$ inch mooring chain, having been cut to the required length, is shackled into the ring of the lower attachment chains, coiled up and laid with the case. A shackle should be provided, at the lower extremity of this chain, ready to connect it with the central loop of its mushroom sinker. A 7 cwt. mushroom sinker should also be selected, and the $\frac{7}{16}$-inch tripping chain, having been cut to the required length, should be shackled to it, coiled up and laid with it. The number of the mine should be attached to the charge, sinker, and circuit closer, by means of a small wooden tally on each, and they are then ready to be placed together on a truck, and transported by the tramway to the wharf, for shipment in the lighter which conveys them to the place where they are to be placed in position.

Mooring a 500 lbs. ground mine

The mode of mooring a 500 lbs. ground mine is shown in *Plate* XVII. The case, having been loaded and fitted with fuzes, &c., in a similar manner to the buoyant charge, is prepared by attaching a 3 cwt. oblong sinker to it, by means of $\frac{3}{8}$-inch chains, passing round it close behind the rings provided for the lugs; the chains run through the rings on the sinker at each end. A mooring chain, with two legs, is then shackled into the

⅜-inch chains round the case, and secured to the coupling screws of the rings carrying the lugs, to prevent any tendency to slip towards the centre, and a shackle is provided, in connection with the centre ring, for the attachment of the Bessemer steel mooring rope from the circuit closer. A ⅜-inch tripping chain, having been cut to the required length, is then shackled to one of the eyes of the oblong sinker, coiled up and laid with it. This completes the connections, and the case is ready to be transferred, by the tramway, to the wharf for shipment. The circuit closer for a ground mine is prepared in precisely the same manner as for a buoyant mine. Each mine and its corresponding circuit closer should be provided with a number, as before described.

Electrical connections of circuit closer and main cable.

When the charges, circuit closers, &c., have arrived at the wharf, they may either be at once lowered into the lighter and the electrical connections made on the deck of the vessel, or they they may be made on the wharf and then lowered into the lighter. This latter plan is preferable where the lift, from the vessel to the wharf, is sufficiently short to admit of the several parts, viz., the circuit closer, charge and sinker, being lowered separately, without interfering with the attachments connecting them: there would be more room on the wharf, than could possibly be provided on deck of a vessel of the size suited for transporting the mines to their respective positions. In order to complete the electrical connections, it is only necessary to form the conducting cable from the circuit closer to the charge, the main conductor, from the charge to the shore, and the outer line (L) terminal of the fuze plug of the charge, into a forked, insulated joint, as described at page 134, and shown in *Fig.* 8, *Plate* XXXIV. For this purpose, the wire armouring is stripped off about 9 inches of the cores to be connected, and the wires turned over and formed into turk's heads, as already described. To make this joint, the case should be turned on its end, and the dome removed and subsequently replaced and screwed firmly down into position.

Improved dome for buoyant mines.

In the newest form of case for buoyant mines, an improvement has been effected in the dome, so that the electric cable may be introduced in a vertical direction, for connection with the fuze plug terminals, &c. The new form of dome is shown in *Plate* XLII., *Fig.* 1, and differs from that originally adopted, in having the opening for the main electric cable at the point *a*, slightly on one side of the bottom, a clip being provided, with screw bolts and nuts, to grip the cable at this point. It has been found necessary to introduce the cable into a buoyant charge in a vertical direction, as when turned at an angle, as was necessary with the old form of dome, the small amount of motion, which is unavoidable in the case of a buoyant mine, always broke the armouring wires short off at this point. The

DOMES FOR SERVICE CASES.

Fig. 1.

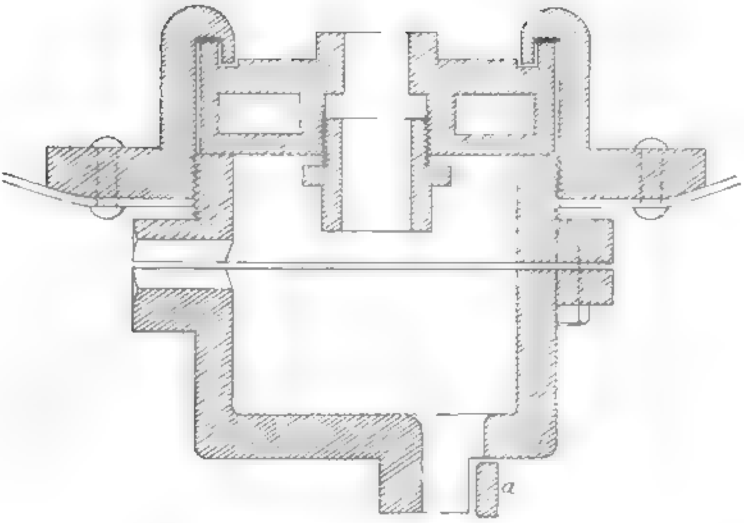
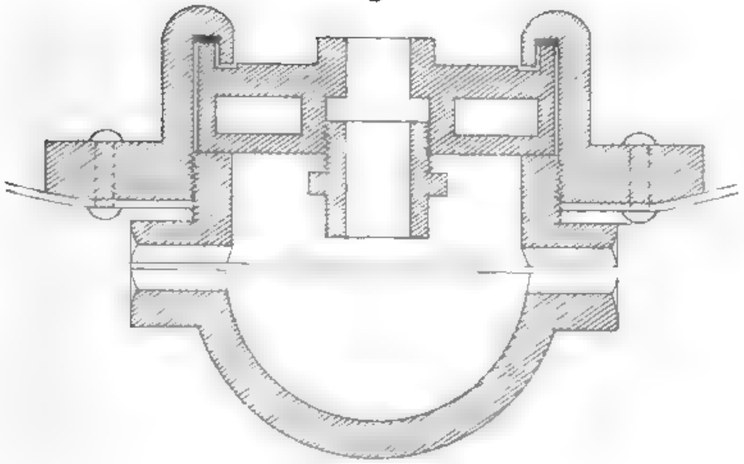


Fig. 2.



Lithographed at the S M E Chatham. B Butler, Corpl R E.

original form of dome, shown in *Plate* XLII., *Fig.* 2, is preferable for a ground mine, as it allows the electric cable to pass out in a vertical direction, it has consequently been retained for this purpose.

Electric cables to be stopped to mooring and tripping arrangements.

The electric cable, connecting the charge to the circuit closer, should be stopped, with plenty of slack, to the Bessemer steel mooring rope at intervals of about 6 feet. The main electric cable, from the mine to the shore should be stopped, at similar intervals, to the mooring chain, connecting it to the sinker in the case of a buoyant mine, as well as to the tripping chain in both buoyant and ground charges, plenty of slack being similarly allowed in both cases.

Mooring 100 lbs. electro-contact mine

The mode in which a 100lbs. electro-contact charge, on the branch system, is to be moored is shown in *Plate* XVIII. and the details of the connections of the circuit closer in *Plate* IV., page 52. These latter are very similar to those already described for the charges with the detached circuit closers. The case and circuit closer should be tested to ascertain that they are watertight, in the manner already described. The fuzes used for this form of mine are No. 7 Detonator, electric, platinum wire, they are two in number for each charge, and connected together in simple continuous circuit. The first operation is to test the fuzes for continuity and resistance: this should be done by means of 2 Daniell's cells, with a set of resistance coils and Wheatstone's bridge, in connection with a galvanometer, in a manner which shall be hereafter described. It is necessary to ascertain, that the fuzes to be used do not possess any abnormal electrical resistance; their proper working resistance should be from $\frac{1}{4}$ to $\frac{1}{2}$ an ohm for each. This done the fuzes should be waterproofed with sealing wax varnish, as already described, and numbered to correspond with the mine for which they are intended.

Test of platinum wire fuzes.

Connection of fuzes and circuit closer

The fuzes are next connected with the circuit closer. For this purpose the cap *b*, *Plate* IV., page 52, is removed and the insulated wire *f*, connected with the fuze plug, drawn out through the top of the circuit closer. A sufficient length of conductor is then cut off from the wire *f*, to connect the fuzes with the screw on the side of the insulated disc: this length is provided for in the wire *f*, supplied with the apparatus. The dome is then removed, and the connection with the disc made: the earth connection is completed, by means of the body of the circuit closer, through the upper attachment screws, in connection with the springs, and the metal pillars supporting the apparatus. Tests having been made, to prove that the insulation and conductivity of the several parts are correct, and that the contact screws are set at the necessary amount of sensibility, the copper dome is replaced and screwed firmly down. The fuzes are now attached to the wires, *f* and *g*, *Plate* IV., page 52, and their connections well insulated with indian-rubber tape,

to prevent ingress of damp, as previously described. The projecting cones *a*, *a* of the fuzes should now be pushed into the holes in the gun-cotton priming disc, and the cap *b* replaced.

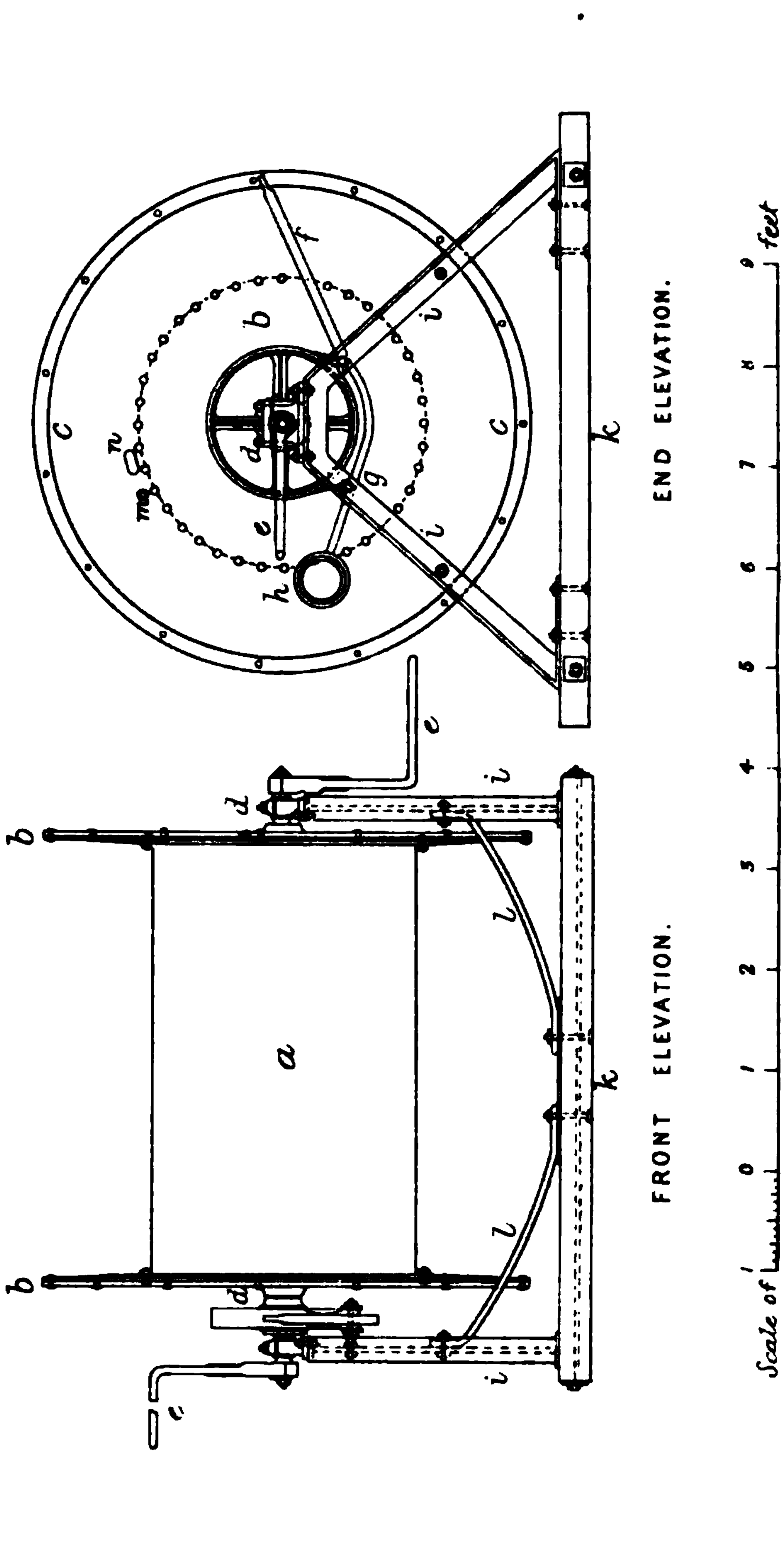
Loading the case. In loading the case, it is necessary so to dispose the gun-cotton discs as to admit of the circuit closer being introduced into the charge without difficulty. The case should be pushed into the wooden jacket before the loading is commenced: in other respects, this operation should be carried on in precisely the same manner as described for the larger charges. As soon as the loading has been completed, the circuit closer, with fuzes and priming attached, should be inserted in position and screwed firmly home, making all watertight.

Connection of branch cable. The branch cable, from the charge to the *T* connecting box, having been pushed through the base plug *n*, *Plate* IV., page 52, is connected with the outer terminal of the fuze plug by an indian-rubber tape and tubing insulated joint, as previously described, a turk's head being formed in the usual way, and the branch cable being tightly gripped by the clips on the bottom of the wooden base plug. The wooden base plug should then be put in its place and secured to the wooden jacket by means of the rods, with screws and nuts, provided for that purpose. The other extremity of the branch electric cable, should then be attached to one terminal of the disconnector and the joint insulated, as shown in *Fig.* 6, *Plate* XXXII., and the cable made into a hank as in the other mines. This done it would be ready to be transferred to the wharf for shipment.

Preparation of electric cables. The mode of testing electric cables shall be explained hereafter. In preparing the single armoured cable for connection with a charge, two methods, suitable to different circumstances, may be adopted. The first is to measure, from the chart, the length required to connect each particular mine with its junction box, add one third for slack, &c., and cut the cable. The second is to coil the cable on drums in half mile lengths, as received from store, commence reeling out from the mine, after the latter has been put in position, and on reaching the junction box, cut off the length required. The first arrangement is preferable when the length of the cable is short, for example 200 yards or less: under such circumstances it may be prepared previously in the lengths required, made up in coils, tied with spun yarn, and numbered to correspond with the mine for which it is intended. In these short lengths, it may be payed out from the coils so made, without difficulty. The second method is more economical in cable, but not so quickly executed.

Preparation of multiple cables. The multiple armoured cables are of considerable weight, and must always be payed out from drums specially provided for the purpose, according to designs approved by the Torpedo Committee. Drums for the single cable have also been similarly approved and adopted for service.

WROUGHT IRON DRUM,
FOR MULTIPLE ARMOURED CABLE.



Lithographed at the S. M. E., Chatham. *B. Butler. Corpl. R.E.*

Plate XLIII. shows a side and front elevation of the service drum for half a nautical mile of seven cored, armoured, multiple cable. It consists of a barrel or core *a*, formed of a cylinder of $\frac{5}{16}$-inch wrought iron plate, 2 feet 9 inches in diameter, and 4 feet 6 inches long. Each drum is composed of not more than two pieces, riveted to joint $\frac{5}{16}$-in. plates, placed inside, by a double row of $\frac{1}{2}$-inch rivets: the rivet heads on the outside of the drum are made flush. The end plates are formed of wrought iron discs, *b*, *b*, $\frac{5}{16}$ inch thick, in one piece, and 5 feet in diameter, connected to the barrels by $\frac{5}{16}$-inch angle iron, $2\frac{1}{4}$ inches by $2\frac{1}{4}$ inches, each angle iron in one piece, and riveted on with $\frac{1}{2}$-inch rivets; the angle iron is fixed inside the barrels and the riveting, on the outer surface of the barrels and inner surface of the ends, is flush. Each end plate is slightly dished, so that the edges may project outwards. The end plates are stiffened at their outer edges by fillets *c*, *c* of wrought iron, $1\frac{1}{2}$ inches broad, and $\frac{1}{8}$ inch thick, riveted on in one piece, the rivets on the inner side being flush. A cast iron box, *d*, to receive the axle, and with key ways for the reception of four keys, is riveted to each end plate; the riveting on the external surface being flush. The axle is of wrought iron, 2 inches square, turned at the ends and fitted to receive the brake, bearings and handles: the barrel is secured to the axle by 8 wrought iron keys, 4 to each cast iron box, on the end plates. Two handles, *e*, *e*, formed of round iron, one inch in diameter, fitted to each end of the axle, and of the form shown in *Plate* XLIII., are supplied. A brake *f*, formed of an iron band, attached to a handle, working on a pivot *g*, and with a counterbalance weight *h*, is attached for use in paying out the cable from the drum. The standards *i*, *i*, to support the drum, are of $\frac{3}{8}$-inch T iron 3 inches by 3 inches, forged to the form shown in *Plate* XLIII., and with feet of extra width and thickness: they are fitted with cast iron plummer blocks, secured to the standards by bolts and nuts and fitted with properly bored gun metal bearings, for the reception of the axle, pin to brake, &c. The standards are secured to bottom frames of oak *k*, *k*, 6 inches by 4 inches, morticed and tenoned, and bolted together by two $\frac{5}{8}$-inch iron bolts and nuts, extending from side to side of the frame: the standards are attached to these by half-inch bolts and nuts, as shown in the plate, and are braced by 1-inch round iron stays *l*, *l*, by means of $\frac{5}{8}$-inch bolts, with wrought iron connecting plates at the top and washers at the bottom. The whole of the wrought iron is of the best South Staffordshire quality, and the workmanship soundly done. Two holes are provided in one of the end plates; one marked *m*, round, through which an iron hook is passed, to grip the cable at the point where it is first attached to the drum for winding; this hook is provided with a nut, to be screwed firmly up on the outside, for this purpose: the other hole *n* is oval, and

Drum for multiple cable.

through it the inner end of the cable is passed, in such a manner that it may be easily got at for testing or other purposes.

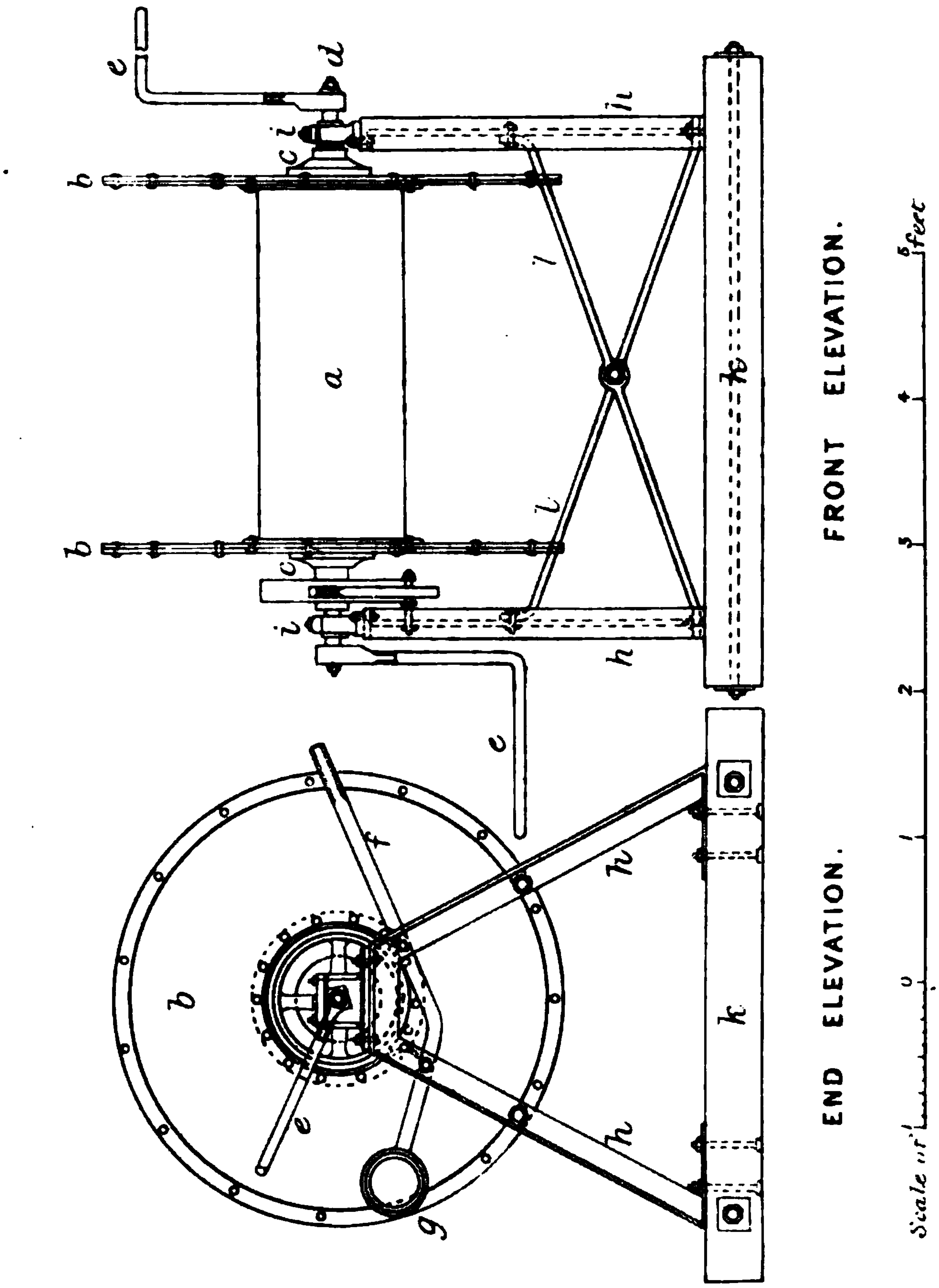
Drum for single armoured cable.

Plate XLIV. shows a side and front elevation of the approved form of drum, for one nautical mile of the single, armoured, electric cable. It is very similar in form and construction to the drum for multiple cable, already described, though smaller in size, and consists of a barrel or core, *a*, 1 foot in diameter and 2 feet 6 in. long, formed of one piece of $\frac{1}{4}$-inch wrought iron plate, rivetted to a $\frac{1}{4}$-inch joint plate, placed inside, by a double row of $\frac{3}{8}$-inch rivets, the rivet heads being flush on the external surface. The end plates *b b* are formed of one piece each, $\frac{1}{4}$ in. thick and 3 feet 2 inches in diameter, slightly dished, so that the edges may project outwards, and stiffened at the outer edges by fillets, in one piece, riveted on, the rivet heads being flush inside. The barrel is connected to the end plates by $\frac{1}{4}$-inch angle irons, $1\frac{3}{4}$ inches by $1\frac{3}{4}$ inches, riveted on from the inside, the rivet heads on the inside of the end plates and on the outside of the drum being flush. Cast iron boxes *c*, *c*, to receive the axle, are provided and are similar to those of the larger drum, being however of smaller size. The axle *d* is of wrought iron, $1\frac{1}{4}$ inches square, turned at the ends and fitted for the reception of the handles, brake and bearings. It is secured to the barrel by 8 wrought iron keys as before. The handles *e*, *e* are of $\frac{7}{8}$-inch, round, wrought iron and are fitted for attachment to the ends of the axle. The brake *f* and counterpoise *g* are similar to those of the larger drum, but of smaller size. The standards *h*, *h* are formed of $\frac{3}{8}$-inch T iron, $2\frac{1}{2}$ inches by $2\frac{1}{2}$ inches, forged to shape as before and fitted with plummer blocks to rececive the axle and brake pin. The plummer blocks *i*, *i* are secured by $\frac{1}{2}$-inch bolts and provided with gun metal bearings, as in the larger drum. The standards are secured to bottom frames *k*, *k* of oak, 4 inches by $4\frac{1}{2}$ inches, morticed and tenoned, and bolted together by $\frac{1}{2}$-inch iron bolts and nuts, extending from side to side: the standards are attached by $\frac{1}{2}$-inch bolts and nuts and braced by round, wrought iron stays *l*, *l*, $\frac{5}{8}$ inch in diameter, with connecting plates and washers, as in the larger drums. A hole is provided in one of the end plates, close to and within the circumference of the barrel, and a corresponding hole is formed, in close proximity to it, in the barrel itself; the end of the cable is passed from the interior through these, and pulled for an inch or two through the end plate, it is thus secured in commencing, to wind the cable on the drum, while by this arrangement the conductor may be easily reached for testing or other purposes. The whole of the wrought iron is of the quality of best South Staffordshire, and the workmanship very carefully executed.

Wooden drums for use with

It may sometimes be desirable to pack the electric cable on wooden drums for transport, and the following description of drum has been approved by the Torpedo Committee for this pur-

WROUGHT IRON DRUM,
FOR SINGLE ARMOURED CABLE.



Lithographed at the S.M.E. Chatham. — *B. Butler, Corp[l] R.E.*

WINDING APPARATUS.

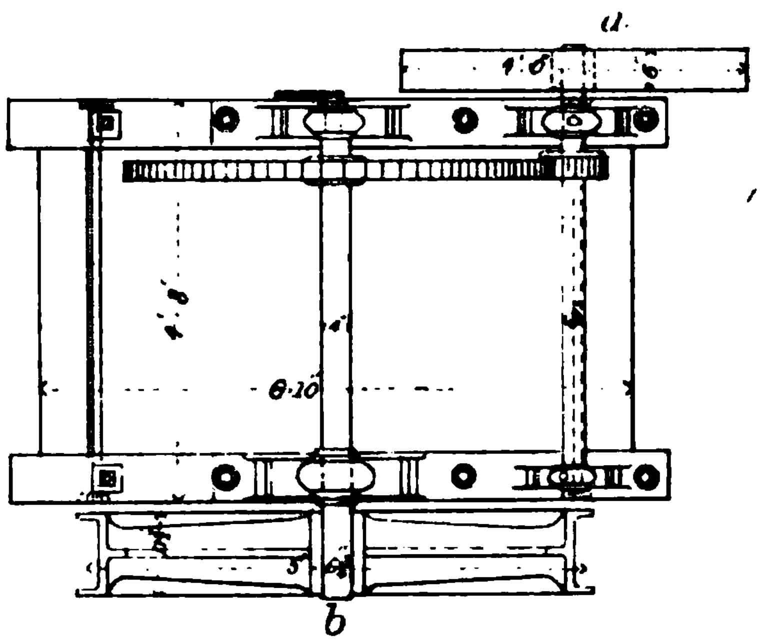


Fig. 1.

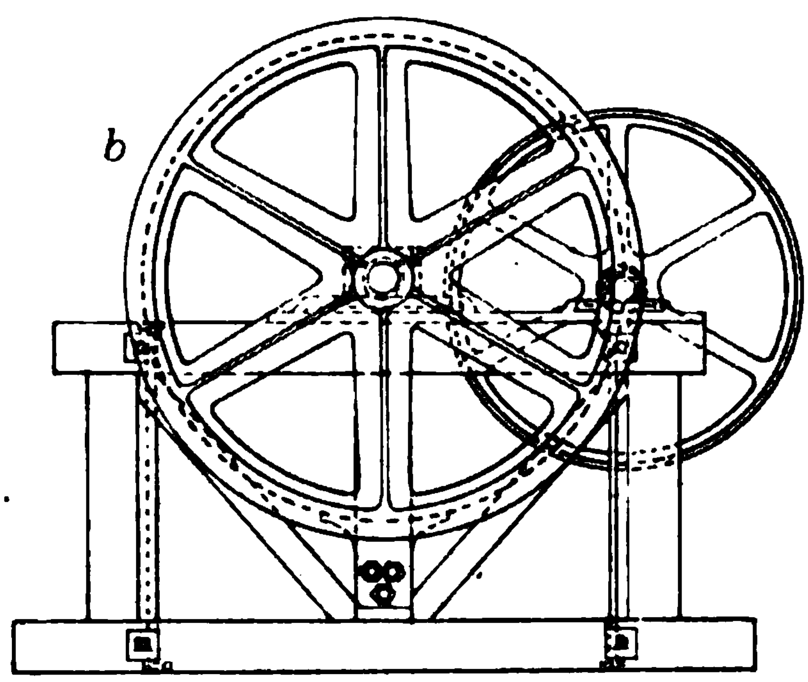


Fig. 2.

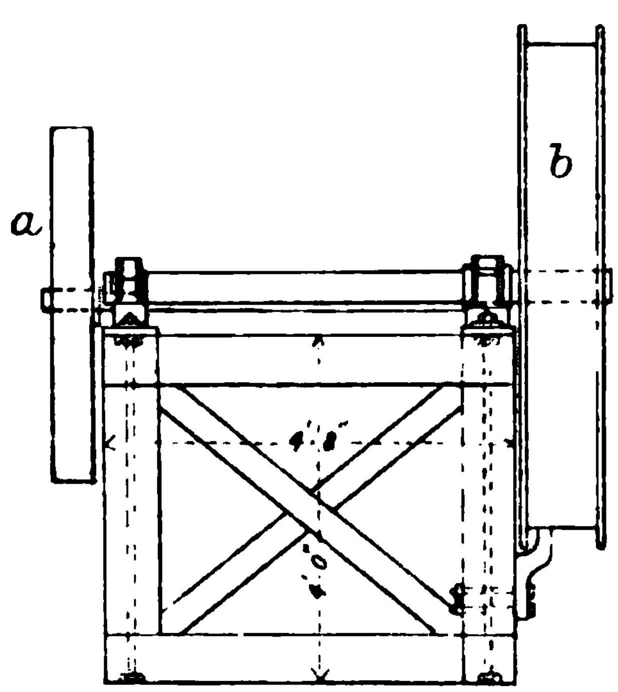


Fig. 3.

Lithographed at the S. M. E., Chatham — *B. Butler, Corp[l]. R. E.*

pose. It consists of a barrel 2 feet in diameter, and 2 feet 9 inches long in the clear, between the flanges or discs forming the ends, these latter being 5 feet in diameter. The body is formed of three centres $21\frac{1}{2}$ inches in diameter, each formed of two $1\frac{1}{2}$-inch deal boards, arranged with the grain of the wood crossed, and with a 2-inch hole through the centre. The centres are connected by laggings formed of deal, 2 feet 9 inches long, 3 inches broad and $1\frac{1}{4}$ inches deep, secured to each centre by two 3-inch nails. The flanges are made of three thicknesses of $1\frac{1}{4}$-inch deal boards, with the grain of the wood crossed, forming a total thickness of $3\frac{3}{4}$ inches, well screwed together both inside and outside by 3-in. screws: the inner board of the three is 6 in. less in diameter than the two outer, in order to afford room for the attachment of laggings outside, after the cable has been wound on the drum: the two outer boards are tyred together with $\frac{5}{16}$-inch feather edged iron, 2 inches wide. The flanges are secured to the barrel by means of eight $\frac{5}{8}$-inch bolts, passing through a pair of wrought iron plates, 2 feet square, $\frac{3}{8}$-inch thick, with a 2-inch circular hole in the centre and a $\frac{1}{2}$-inch square key way cut in the same. For the preservation of the cable during transport, laggings 3 feet long, $4\frac{1}{2}$ inches broad and $1\frac{1}{4}$ inches deep, formed of deal, are nailed on to the inner thickness of the flanges by two 3-inch nails at each end. The drums and inner laggings are planed inside and outside and painted with one coat of paint. They must be put together in a substantial manner and with good workmanship, as considerable strength is required. *electric cables.*

Winder for coiling cable

In coiling the cable, either from a vessel into a tank or from a tank to a drum, it is necessary to employ a winder, which has a large flanged wheel, round which two or three turns of the cable are taken, and this wheel, being in gear with a driving wheel, is worked by a 3-horse power engine; attached to the winder is an index, by which the length of cable is measured off, during the process of coiling. The description of winder, approved by the Torpedo Committee, is shown in *Plate* XLV. *Fig.* 1 shows a plan, *Fig.* 2 a side, and *Fig.* 3 an end elevation of this apparatus. *a* is the driving wheel, for connection with the steam engine used to give motion to the machine: *b* is the winding drum, round which two or three turns of the cable are taken, to give the necessary grip to draw it forward. The whole is supported on a strong wooden frame, fitted with plummer blocks, on which gun metal bearings are placed, to receive the axles on which the wheels revolve. Any portable steam engine, of sufficient power, may be used in connection with this apparatus. A few portable engines of compact form, with vertical boilers, have been provided for stations where suitable engines are not readily obtainable.

Fair leads.

The cable is supported, at intervals of 50 feet, on Fair leads, on wooden frames, carrying a grooved iron axle, and in this manner 6 to 10 knots of cable can be coiled in one day. It is desirable

that the distance along which the cable has to be taken should not exceed 150 yards, to avoid straining the cable unnecessarily. The form of Fair lead recommended for use is shown in *Plate* XLVI., *Fig.* 1 shows an end and *Fig.* 2 a side elevation of these machines. They consist simply of four iron uprights *a, a, a, a,* to give direction to the cable, with a roller *b* in the centre, over which it passes, the whole carried on a strong wooden frame, as shown in the Figures.

Steamer, lighter, and boats, specially fitted for submarine mining service.

In order to carry out the service of defence by submarine mines, a steamer of the tug class, one or more lighters, capable of carrying from 7 to 21 mines complete, with their circuit closers, electric cables and mooring apparatus, one or more steam launches or small steamers, specially fitted, and one or more ship's boats of the pinnace class, also specially fitted, are necessary. For a station where a considerable amount of work is to be done, the following, which may be considered a unit for submarine mining service, would be required:—1 tug steamer, 2 lighters, 2 steam launches, or small steamers, and 2 pinnaces.

Tug steamer.

An ordinary paddle-wheel, tug steamer would answer very well for this service; she would be employed in towing the lighters and in paying out the multiple cable.

Lighters.

Lighters are required to convey the mines, complete, with electric cables, circuit closers and mooring gear, from the shore to the position to be defended. Each multiple cable is composed of seven cores, the mines are therefore divided into sections of seven, and the lighter employed should consequently possess sufficient deck room to carry a multiple of seven, (7, 14, 21, &c.), mines, 14 being the most convenient number for the purpose. She should not draw more than 5 or 6 feet of water. The iron mortar vessels built for service during the Crimean war, are very suitable for this purpose, they are 62 feet long and 20 feet broad on the deck, 6 feet 7 inches deep, and draw about 4 feet 6 inches of water. Each of these boats can carry 14 mines, complete, on her deck.

Small steamer.

Plate XLVII. shows a small steamer, of the class which seems most suitable for this service. She may be described as a small tug, 56 feet long, with 13 feet beam, 7 feet 6 inches in depth, and built of iron. She is propelled by engines of 25, nominal, horse power. Vessels of this class are now much used as tugs for river service, and would be quite big enough to tow any vessel that might be required in connection with submarine mining operations. This design has been furnished by Messrs. J. & W. Dudgeon, Ship builders and Engineers, of Cubits Town and Millwall, who build a great many small tugs of this class for commercial purposes. She is not too large, her consumption of fuel is not great, she possesses considerable speed and sufficient deck room to carry a drum of multiple cable, of the size described at page 161 as that adopted for service. Vessels of this class would be large enough to pay out the multiple cable, in fine

FAIR LEAD FOR ELECTRIC CABLE.

Fig. 1.

Fig. 2.

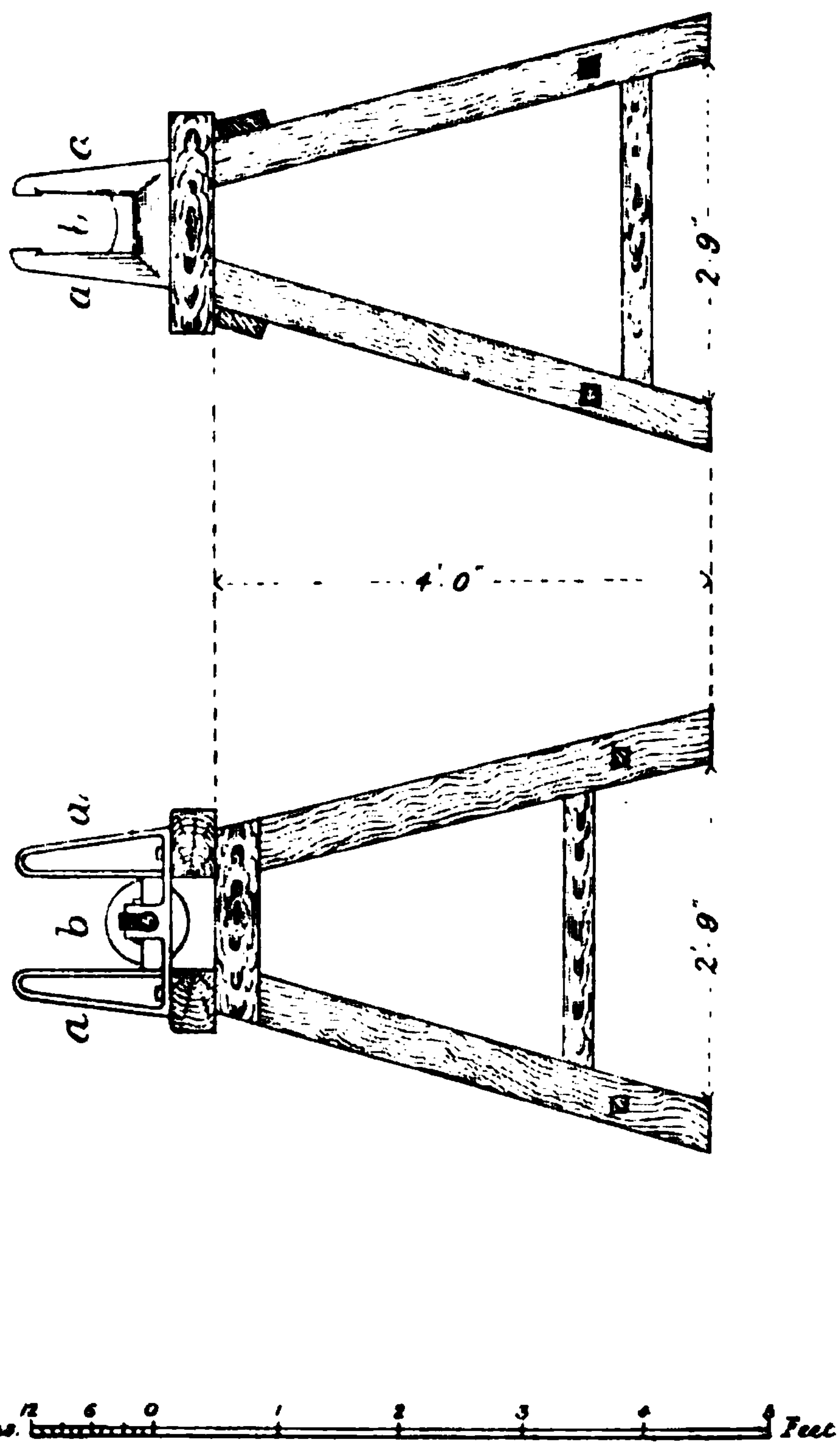


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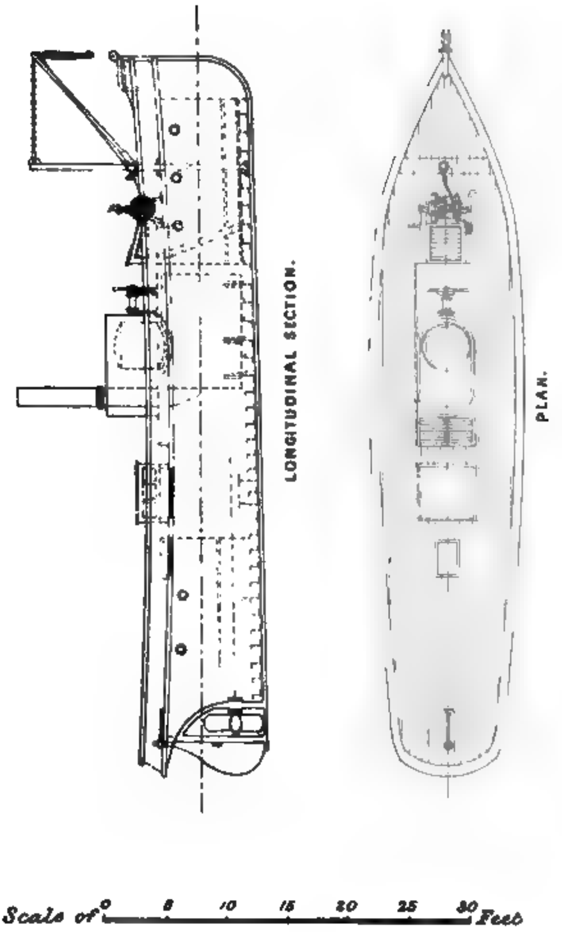
PLATE XLVII.

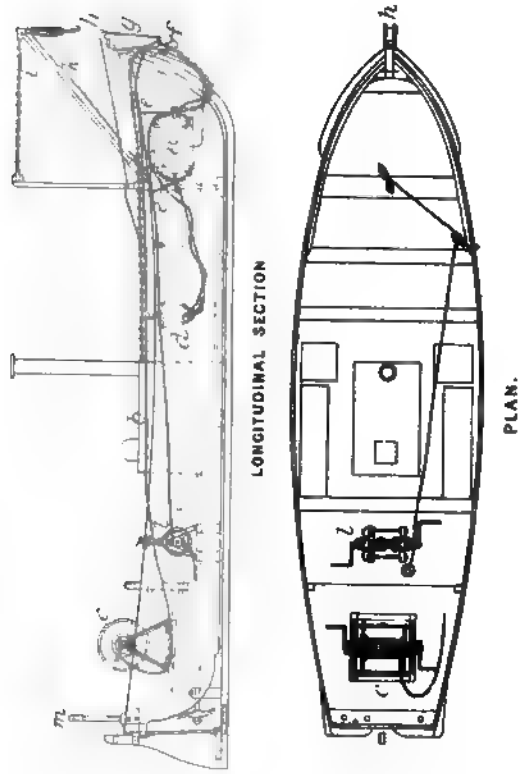
SCREW STEAMER FITTED FOR
SUBMARINE MINING SERVICE.



Lithographed at the S. M. E., Chatham. *B Butler, Corpl. R.E.*

PLATE XLVIII.

STEAM LAUNCH FITTED FOR SUBMARINE MINING SERVICE.



Scale of 0 5 10 15 20 Feet

Lithographed at the S M E., Chatham. B. Butler, Corpl R.E.

weather, if a larger tug steamer were not available, and if fitted with a very simple derrick at the bow, from which a mine could be slung, with a crab to supply the necessary power, and a small projecting crutch with a sheave, as shown in *Plate* XLVII., would be able to perform every service connected with placing the mines in position, as well as the other necessary work. The derrick, crab, and projecting crutch would be of the patterns approved for service by the Torpedo Committee, which shall be hereafter described. The dimensions of these special fitments are shown in *Plate* XLVII.

Steam launches. Where steamers of the class described in page 164 and shown in *Plate* XLVII. are not available, a 42-ft. steam launch, fitted as shown in *Plate* XLVIII., may be used for placing the mines in position or taking them up when required for examination. The mine to be placed in position is deposited in the boat, with its electric cable, circuit closer, and mooring sinker, complete, as shown in the plate. *a* is the mine, *b* the electric cable, carried from the drum *c* to the charge and ready connected; *d* is the circuit closer, attached to the charge by its electric cable and mooring rope. The charge and circuit closer are made fast in the boat by lashings *e*, *e*, *e*, to prevent motion and derangement, during transport to the point where they are to be placed in position. *f* is the mushroom sinker, attached by its mooring chain to the mine, fitted with its tripping chain, and suspended by a slip rope *g*, over a small crutch *h*, with a sheave, projecting over the bow. *Crutch.* The slip rope is so lashed that it may be released and the anchor set free very quickly. *Derrick.* *i* is a derrick provided with a fall *k*, and double block, for hoisting the mine out, or for any work required in taking up a mine for examination. The derrick is formed of an iron tube gaff, 3 inches in diameter and $\frac{3}{8}$ inch thick, and is 10 feet 6 ins. long: it is attached to a mast 12 feet 3 inches long, also formed of tubular iron of the same dimensions as the derrick itself, by means of a $\frac{5}{8}$-inch iron chain, 6 feet 6 inches long, secured to eyes as shown in the plate. The mast passes through an additional strong thwart 6 inches thick, fitted to the strengthening piece of the sides between the two foremost thwarts, and is secured to the boat by a step, as shown in the plate, and strengthened at its junction with the gaff by an iron tube, 1 foot long and $\frac{1}{4}$ inch thick, shrunk on: it is provided with a projection, 2 inches long and 2 inches in diameter, to ship into the step, in which an iron tube is fitted on which the whole derrick may be turned. The lower end of the gaff is attached to the mast by a hinge, admitting only of vertical motion: its upper extremity is provided with four eyes, one above for the attachment of the chain from the mast, one below for connecting the hook of the upper purchase block, and one on each side for the steadying guys. The tackle consists of a double and single 6-inch iron block, fitted with a $2\frac{1}{2}$-inch rope fall, about 18 fathoms long. An additional leading

block is required, in the case of a steam launch, to carry the fall clear of the boiler and engine, from the derrick to the crab.

The stern sheets of the boat must be strengthened, to enable her to carry the weight of the electric cable and drum. The screws of these boats project considerably, and much care is required to prevent them striking any object offering much resistance, such, for example, as a circuit closer, which would inevitably bend and damage the blades. In order to carry the electric cable clear, during the process of paying out, a leading sheave *m* is fixed on bearings at the stern of the boat.

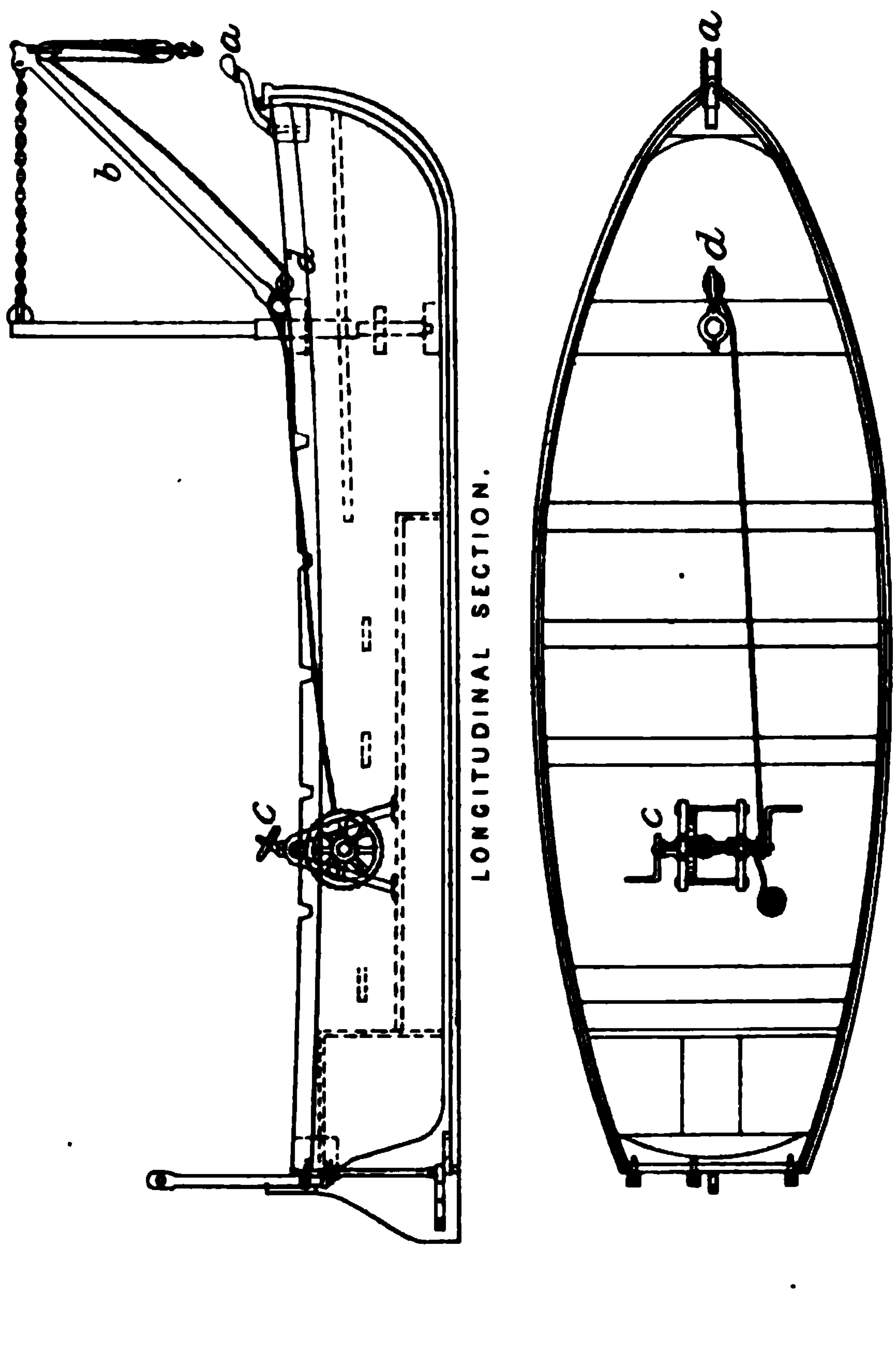
The special fittings described, as required for the steam launch, are precisely similar to those recommended to be supplied for the small steamer shown in *Plate* XLVII., the details of arrangements having been modified to suit the different classes of vessel. When steamers of this class are available, steam launches would not be required, as the former would be capable of performing all the work to be done by the latter in a more efficient manner.

Crab. The crab *l*, *Plate* XLVIII. is the ordinary commercial pattern, slightly altered to suit this particular service. The length of the inner barrel is reduced, to admit of two warping barrels being placed outside, one on each side, and a small friction brake is fitted to the small pinion shaft, worked by the handles, instead of the ordinary brake on the larger shaft. The object of these alterations is to improve the crab for this special service, while its size is kept down, so that it may be conveniently worked in a boat of the class employed. Two sizes of crabs have been provided for service, to suit every variety of work. The dimensions of the larger are as follows: the inner barrel is 18 inches long and 5 inches in diameter; the warping barrels are 8 inches long, with a greatest diameter of 9 inches, and least diameter of 5 inches; the height of the axis of the inner barrel above the platform is 15 inches, and its extreme height above the same 17½ inches; the extreme height of the warping barrel above the platform is 19½ inches; the distance between the supporting legs is 22½ inches, and the spread of the legs on the platform 29 inches; the extreme breadth of the crab, with its handles shipped is 5 ft. 10 in. The inner barrel of the smaller crab is 14½ inches long and 4½ inches in diameter; the warping barrels are 8 inches long, with a greatest diameter of 9 inches and least diameter of 5 inches; the height of the axis of the barrel above the platform is 12½ inches, and its extreme height above the same 14¾ inches: the extreme height of the warping barrel above the platform is 17 inches; the distance between the supporting legs is 19 inches, and the spread of the legs on the platform 26½ inches; the extreme breadth of the crab, with its handles shipped, is 5 feet 6 inches.

Pinnaces. Specially fitted pinnaces, or boats of that class, are required to attend to the connections between the multiple and single cables, during the process of placing the mines in position, to land the

PINNACE FITTED FOR

SUBMARINE MINING SERVICE.

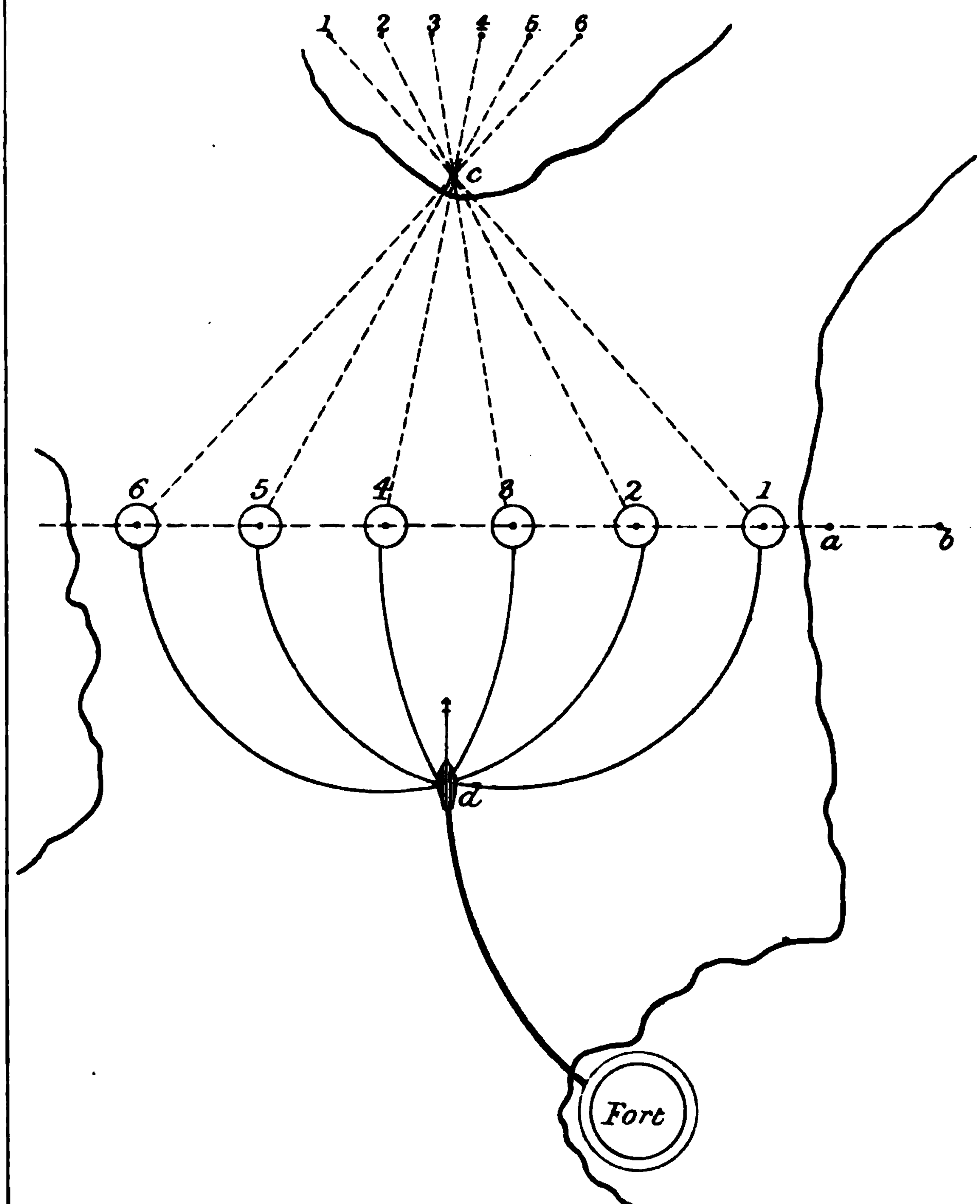


Lithographed at the S. M. E., Chatham.

B. Butler. Corpl. R. E.

PLATE L.

MODE OF SUBMERGING MINES.



Lithographed at the S M E., Chatham. *B Butler, Corpl R. E.*

shore ends of the multiple cables and for other similar services. An ordinary man-of-war's pinnace, from 28 to 36 feet in length, of the class employed in Her Majesty's Service, fitted as shown in *Plate*, XLIX., is recommended for this purpose. The fittings consist of a projecting crutch and pulley *a*, a derrick *b*, a crab *c*, and a leading sheave *d*, of precisely the form described as suitable for the steam launch.

Mode of placing mines in position, proposed by Lieutenant Anderson, R.E.

The following proposed mode of placing submarine mines in any given position, and of dealing with the cables in connection with the different charges, has been drawn up by Lieutenant Anderson, R.E., and is applicable where the land or river banks are conveniently situated for erecting the poles. Its general principles have been adopted in all operations of this nature, and it has been found to answer very well in practice. The mode which is recommended for placing mines in position, and which has been approved bp the Torpedo Committee, is simply a modification of this method.

The direction of a line of mines, to be placed across a channel, may be determined by two poles previously erected on the shore, as shewn at *a* and *b*, *Plate* L. The arrangement to give the intersections on the above mentioned alignment, where each mine is to be placed, is shewn by the poles marked *c*, and 1, 2, 3, 4, 5, 6, to correspond with the numbers of the mines.

The proposed mode of placing the charges in position is as follows:

Soundings are first taken at the required points, and the length of mooring line for each charge determined accordingly. The sinker is suspended from the davit of the steam launch, and everything made ready to let it go with a run. The electric cable should be stopped to the mooring line between the charge and the anchor, and a strong mooring chain, or wire rope, is provided to connect the charge to the circuit closer, so that, by this chain, both the charge and anchor may be raised if required. The electric cable, between the circuit closer and charge, should be stopped to the chain, or wire rope, in the same manner as from the charge to the anchor. The length of the electric cables, from the anchors of the different charges to the point *d*, on which they converge, would vary according to the positions of the charges with regard to the centre line of the channel. Each electric cable is coiled on a small portable drum, so that it may be easily moved in and out of the steam launch.

To place the first mine.

To place the first charge, the steam launch, (with the sinker connected with the charge and circuit closer, by moorings of proper length, as above described, and suspended by the davit), is moved into the exact alignment given by the line *a b*, proceeding only fast enough to obtain steerage way; as soon as the bow of the launch arrived at the intersection given by the alignment *c* 6, the order would be given "let go," and immediately sinker, charge, and circuit closer would be slipped down into

position. The electric cable would then be payed out, directly away from the charge, and taken to the boat *d*, which had been previously anchored in a position 100 yards or more in rear of the centre of the part of the channel to be defended. When many charges are to be placed in the same line, it is recommended, in order to avoid the use of long cables and consequently unwieldy drums, that the cable from each charge should only be long enough to reach to the boat *d*, in which the end of this cable is, for the time being, secured. The next charge, with all its attachments complete, having been arranged as before, the launch would again slowly cross the channel along the alignment *a b*, till her bow arrived at the intersection 5 with the pole *c*, when the anchor would be let go, and the cable of this charge carried in the same manner to the boat *d*. Thus all the charges up to No. 1 would be similarly deposited in position, and their cables carried as far as the boat *d*.

Tests to be made during submergence

Tests, for continuity and insulation, should be made as soon as each electric cable arrives at the boat *d*. When a multiple cable is to be employed for the main conductor, (and if battery power were always used for firing, there would be no objection to the use of such a cable), it would now be a simple matter, by means of insulated joints, to connect each cable to its corresponding conductor. It is advantageous to establish, at this point of the electrical circuit, the junction box into which all the cables from the charges are carried, and in which the connections with the main conductor are made. This junction box would be of the form shewn in *Plate* XXXI., and described at page 123. Where the use of a multiple cable is impracticable, each must be carried separately into the fort, from which the system is to be controlled. It would be convenient to lay the multiple cable, or the separate single cables, from the fort to the anchored boat *d*. This operation might be carried on simultaneously with that of mooring the charges. The objection to it, in the case of cables carried in singly, would be the joint to be made in the boat *d*, for which reason it would, with single cables, be preferable, if possible, to preserve them in one continuous length and lay them from the boat *d* to the fort, after the previous portion of the work had been completed. If single cables are used they should be paid out in parallel lines, so as not to cross each other, in order that each might be conveniently under-run and examined, if required, without fouling any of the others; or the single cables might be all tied together with spun yarn and laid out as one. It is certain that if some systematic manner of placing a series of cables along the bottom of a channel is not adopted, they will become entangled with each other. There is, however, an objection to their being laid out close to each other, viz., that an enemy grappling in that direction would be certain to catch all the cables together.

When everything has been completed, the boat *d* should be removed, its position having been previously carefully determined by bearings, to facilitate any future search for the cables at that point. If a junction box is used, its position may be identified by a buoy* attached to it. The poles or marks, *a*, *b*, *c*, 1, 2, 3, 4, 5, and 6, should also be removed, so that no indication of the locality of the mines may be given to an enemy, their positions having been carefully marked, in order to facilitate their future discovery by those in charge of the operations.

All marks indicating position of mines to be removed.

As there would nearly always be more than one line of mines, it would be necessary to repeat this process for each line, for which purpose a separate set of poles, to mark the intersections, would be necessary.

In working from a chain or hawser, on which the distances have been marked, as described at page 68, the weight of the boat holding on to the chain at the required position, produces a certain amount of sag, greater in proportion to the length of the directing hawser, and this sag must be taken into consideration, and as a check a couple of poles as at *a b*, *Plate* L., or two buoys, where poles could not be used, would be found convenient. For short distances, across the Medway for example, the arrangement with a directing hawser works with sufficient accuracy.

The following mode of placing the mines in position, &c., having been experimentally tested, has been adopted for service. Before proceeding to place a system of submarine mines in position, the whole plan of defence should be carefully matured and laid down on a chart, on a scale of not less than 6 inches to a mile. These charts should be guarded with great vigilance, and every precaution taken to prevent their falling into the hands of unauthorized persons. On the chart should be marked the site of the observing stations, the position of each mine and junction box, and that of the electric cables, both multiple and single. From these charts should be prepared Tables A, B, C, and D, see pages 170, 171, 172, and 173; tables A and B give all the particulars, referring to each individual mine provided with a circuit closer or to be fired by observation; Table C, gives similar particulars for the electro contact mines; and Table D gives all other information, connected with the details of the system. These Tables give all the particulars required for connecting up the mines, such as the lengths of cable to reach from

Placing the mines in position, as approved by Torpedo Committee.

* It has been found convenient to employ a circuit closer jacket, as a buoy for the junction box. Its use is productive of many advantages: it possesses ample buoyancy, and should it appear on the surface of the water, as it is likely to do at certain times of tide, it would be similar to all other floating objects in connection with the mines, and its outward appearance, as a circuit closer, would be more likely to prevent its being touched by unauthorized persons.

TABLE A. GROUND MINES.

No. of Mine.	Size.	In which line.	Depth at L. W. springs	Rise of tide at springs	Distance of top of circuit closer from (a) Bottom at L.W. springs	Distance of top of circuit closer from Surface at H. W. springs	Length of (b) Single electric cable.	Length of (c) Circuit closer Mooring rope.	Length of (d) Circuit closer electric cable.	Length of (e) Tripping chain.	Angle between a and b for fixing position of mines.	Remarks.

The particulars for filling in Column (*a*), will be obtained from the instructions accompanying the Submarine Mine, Defence Chart of the place.

To fill in Column (*b*). Measure, on the chart, the distance between the junction box and the mine, and allow one third more to give sufficient slack for weighing the junction box and for the sweep of the current on, and sag of, the cable in paying it out.

" " (*c*). The distance in (*a*), less 7 feet, will give the bare length from thimble to thimble. This, with 4 feet additional for the two hitches, will be the length to cut.

" " (*d*). To length in (*c*) add 15 feet.

" " (*e*). To depth at H. W. springs add 30 feet.

TABLE B. BUOYANT MINES.

No. of Mine.	Size.	In which line.	Depth of water at L. W. springs.	Rise of tide at springs.	Distance of top of mine from		Distance of top of circuit closer from		Length of					Angle between *a* and *b* for fixing position of mine.	Remarks.
					Surface at L. W. springs.	(*a*) Bottom.	Surface at H. W. springs.	(*b*) Bottom at L. W. springs.	(*c*) Single electric cable.	(*d*) Circuit closer mooring rope.	(*e*) Circuit closer electric cable.	(*f*) Mine mooring chain.	(*g*) Tripping chain.		

The particulars for filling in Columns (*a*) and (*b*), will be obtained from the instructions accompanying the Submarine Mine, Defence Chart of the place.

To fill in Column (*c*). Measure, on the chart, the distance between the junction box and the mine, add to this the distance given in column (*a*), and allow one-third of the whole more, to give sufficient slack for weighing the junction box and for the sweep of the current on, and the sag of, the cable in paying out.

" " (*d*). From distance in (*b*), substract (*a* and 2ft. 6), which will give the bare length from thimble to thimble. This, with 4 feet additional for the two hitches, will be the length to cut.

" " (*e*). To length in (*d*) add 15 feet.

" " (*f*). From distance in (*a*) subtract 4 feet.

" " (*g*). To depth at H. W. Springs add 30 feet.

No. of Mine.	Depth of water at L. W. springs.	Rise of tide at springs.	Distance of T connectors apart.	Distance of top of mine from		Length of			Remarks.
				(*a*) Bottom at L. W. springs.	Surface at H. W. springs.	(*b*) Main Cable.	(*c*) Mooring rope	(*d*) Circuit closer electric cable.	

The particulars for filling in Column (*a*), will be obtained from the instructions accompanying the Submarine Mine, Defence Chart of the place.

To fill in Column (*b*). Measure, on the chart, the distance between the junction box and the end of the cable, and allow one third more for slack.

" " (*c*). From distance in (*a*), subtract 5 feet, which will give the bare length from thimble to thimble. This, with 4 feet additional for the two hitches, will be the length to cut.

" " (*d*). To length in (*c*) add 12 feet.

TABLE D. MISCELLANEOUS.

Multiple Cables.		Junction boxes.					Signalling cables.				Alignment marks.			Remarks.
Size.	(a) Length.	Letter.	Angles for fixing position.		(b) Depth of water at L. W. neaps.	(c) Length of buoy mooring rope.	No.	Length.	(d) Depth of water at L. W. springs.	(e) Length of buoy mooring rope.	Line.	Angles for fixing position.		
			R.	L.								R.	L.	
											Inner.			
											Centre.			
											Outer.			

To fill in Column (*a*). Measure, on the chart, the distance between Stations *a* and the junction box, and allow one-third more for slack.

" " (*c*). Insert depth from (*b*). Allow 4 feet in addition to this for the two hitches. This will be the length to cut.

" " (*e*). To (*d*) add the rise of tide at springs. Allow 4 feet in addition to this for the two hitches. This will be the length to cut.

the charges to the junction boxes, the lengths of multiple cable to reach from the junction boxes to the shore, &c. The cable lengths are measured direct from the chart, one third extra being allowed in every case for slack.

Special vessels and boats.

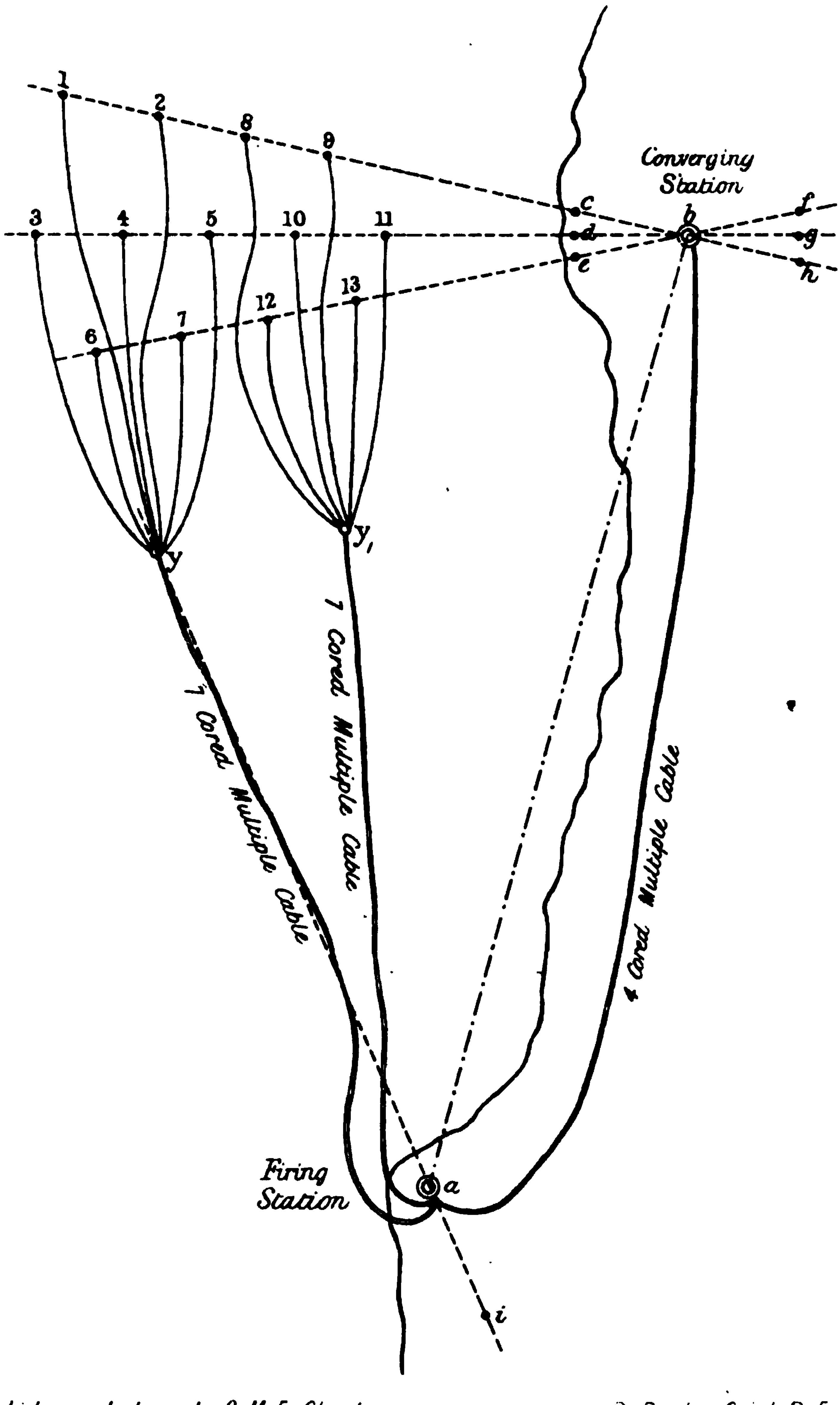
The vessels required, for placing the cables and mines in position, have been already described, viz.:—One steamer, paddle or screw, for laying multiple cables and towing the lighters, &c. Two small steamers or steam launches, specially fitted, for placing the mines in position. Two 36 feet pinnaces, specially fitted, for making the connections at the junction boxes. Two lighters, each large enough to hold not less than fourteen 500lb. mines complete with sinkers, circuit closers, and single electric cables on drums. The steamer will not require any special fitments, except a fair lead over the stern for the multiple cable. The men required for work in the different boats and vessels will be as follows. For the steamer, besides her regular crew, 1 officer and 8 seamen, for laying out the multiple cables. For each steam tug or steam launch, besides her regular crew, a detachment of 5 N.-C. officers and sappers, with an officer, for laying out the charges. For each pinnace, 1 N.-C. officer and 3 sappers. For each lighter, 1 officer and 12 seamen: these men are simply intended to assist in loading and unloading the lighters, and their duties would chiefly involve a certain amount of manual labour.

Marking alignments.

Wherever it is practicable, poles should be erected on shore giving the alignments for laying the mines, according to the system already described. If this is not practicable, beacons, with weighted cages to balance them, should be employed and lowered into position from a lighter. Poles should be set up at the converging station, at not less than 100 yards either to seaward or inshore thereof, as is most practicable, giving the directions of the outer, middle, and inner rows of mines. The radiating point should be a staff and flag, erected immediately over the observing sights at the converging station, and the poles should be placed perfectly upright and with a flag on each, so that they may be readily distinguished. A staff and flag should be similarly erected over the observing arc at the firing station, and, in advance of it, poles should be placed, when practicable, giving the general alignments for laying out the multiple cables, as shown in *Plate* LI.

Suppose *a* to be the firing station and *b* the converging station, poles should be set up at *c*, *d*, *e*, or at *f*, *g*, *h*, to give, in connection with a flag over the pivot of the observing telescopes, the alignments of the three rows of mines, and a pole should if practicable, be set up at *i*, giving the direction to be steered in paying out the multiple cable belonging to the group of mines numbered 1 to 7. The angles, subtended at each mine by the base *a b*, are taken off the chart and entered in the Tables A and B, and from these

MODE OF SUBMERGING MINES.



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copied into a note book, namely, the angles *b* 1 *a*, *b* 2 *a*, *b* 3 *a*, *b* 4 *a*, *b* 5 *a*, &c., as well as the angle *b y a*, for the position of the junction box.

Buoying positions of mines.

The operation of buoying the position of each junction box and mine is then commenced. For this purpose small Nunn buoys, or billets of wood, attached to 1 cwt. pigs of ballast, by buoy ropes of 2-inch tarred rope, may be used. These latter should be cut of sufficient length to show at all times of the tide, and the buoys might be painted red for the outer, green for the middle, and blue for the inner row. They should also be marked conspicuously with the number of the mine to which they refer. The buoys for the junction boxes might be painted black and lettered A, B, &c., while those for the ends of the cables for the electro-contact mines, might be similarly painted and numbered 1, 2, &c. In practice the following system has been adopted. The small steamers or steam launches, each with a number of buoys and pigs of ballast on board, proceed first to buoy the position of the junction boxes, making use of the sextant to obtain the exact position. This being done, they next proceed along the alignment, keeping the pole giving the direction of the particular line of mines, and that over the converging station, in line over the stern. The officer has a sextant with the angle of the first mine in the line, *a*, 1, *b* for example, clamped and keeping one alignment, on the station *b* for example, in view in the eye piece, the steam launch proceeds till the station *a* comes into the field of view, when the ballast and buoy, which are being held over the side, are let go. In this way the positions are very quickly and very accurately marked. Should any doubt exist as to the correctness of the soundings given in the chart, the depth of water should be taken as each buoy is dropped, and the state of the tide carefully noted at the same time. The position of the ends of the lines, of electro-contact mines, and of the signalling cables are marked out in a similar manner.

Laying out multiple cables.

In the meantime the steamer should receive the multiple cables on board, and as soon as the position of the junction boxes is marked, proceed to lay them out. On arrival opposite station *a*, the end of one of the cables should be landed by a boat and conveyed to the testing room, where each core of the cable should be connected to its respective binding screw. The steamer should then proceed to pay out the multiple cable, steering as straight a course as possible, towards the buoy marking the position of the junction box of the particular group of mines to which it belongs. When the buoy is reached, the end may be run off the drum, buoyed and slipped, and the original directing buoy steered for, taken up. The connecting cables, for firing and telegraphic purposes between the stations, should then be laid in a similar manner. Great care must be taken, to avoid bringing any undue strain on the cable in paying out, and, to ensure

this, the speed of the steamer should be as slow as the state of the tide and weather will permit. The end of each core of the multiple cable, is marked with a number to correspond with a similar tally on the home end, the several cores having been previously identified for this purpose. This is required for future reference.

Placing mines in position.

The operation of placing the mines in position is as follows. The two pinnaces, with junction boxes and circuit closer jackets for buoys, should be anchored, each over the end of one of the multiple cables, and these latter, (the ends of the cables), got up and secured in the boats. One of the lighters carrying 14, (or some multiple of 7), mines, complete with sinkers, circuit closers, and single electric cables on drums, should then be towed out by the steamer, and anchored between the pinnaces. The small steamers, or steam launches, should then proceed to place the mines in position, those of the outer line of the group of 7 being laid first, and afterwards those of the middle and inner lines. Each steamer should receive from the lighter a mine complete, arranged as shown in *Plate* XLVIII., the mine or sinker, (if a buoyant mine), being hung to the bow by a slip rope long enough to reach the bottom, the mine (if a buoyant one) and circuit closer, or the circuit closer only, (if a ground mine), slung over the side, and the cable on its drum placed in the stem. Thus loaded, the steamer should proceed to the buoy corresponding to the particular mine she carries. If the tide is running strong, or there is any sea on, or the water is deep, it will probably be found best to anchor and drop into position, but this must be left to the discretion of the officer in charge. The vessel's bow should be placed on the alignment and in the position denoted by the angle given. The mine should then be lowered to the bottom and slipped, and the ballast used for mooring the buoy to mark the position weighed. To ensure the exact position of the mine being observed at station *a*, a flag should be held up in the bow as soon as the buoy is reached, and dropped when the mine is at the bottom. When the vessel is anchored before lowering the mine, it may be found that when the bow is in the alignment, its bearing from station *a* is not correct. When the deviation is slight it may be neglected, for the direction, (from *a*), being taken when the mine is lowered and not when the buoy, (marking the assigned position), is laid down, the only effect would be to make the intervals between this mine and those adjacent to it slightly unequal. To place the mine in the exact alignment as regards station *b* is, however, of the utmost importance. Great care should be taken to keep the bow of the vessel carefully in the alignment, while the mine is being lowered, as no correction for any deviation from it can be allowed at *b*. When the mine is on the bottom, the steamer should next proceed to the pinnace which has the outer extremity of

the multiple cable belonging to the group on board, paying out the electric cable and passing midway between the buoys of the middle and inner rows, so as to keep the cable as far from the mines in these lines as possible. On reaching the pinnace, the end of the cable should be passed into her, the test applied, and, if found satisfactory, the cable should be connected with the corresponding numbered core of the multiple cable.

If the vessel be anchored before lowering the mine, her cables may either be buoyed and slipped, and left to be picked up afterwards, or weighed, as is most convenient. The other mines of the group should then be placed in position in a similar manner. As soon as the last mine of the two groups has left the lighter, she should be towed in for a fresh supply. In the meantime, the other lighter, having been towed out and moored, between the ends of two other multiple cables, the mines she carries will be placed in position in a similar manner, thus ensuring a continuous prosecution of the work. When the junctions have been made in the pinnace, the top of the junction box should be screwed down, and the box buoyed to a circuit closer jacket and lowered to the bottom.

Electrical, signalling connections.

The outer and centre multiple cables, should only have 6 cores in each connected to mines, the 7th core being left, for the connection of the signalling cable, for electric telegraphic purposes. The connection of the signalling cable, within the junction box, should be made before the latter is slipped, the end of the insulated conductor being brought up and attached to the buoy, with sufficient slack to admit of its extremity being brought into a boat, for connection with a telegraph instrument. The number of electrical connections for signalling purposes, will depend on the extent of the lines of mines employed. Such connections are recommended at the flanks and centre for a line of considerable length.

Placing electro-contact mines in position.

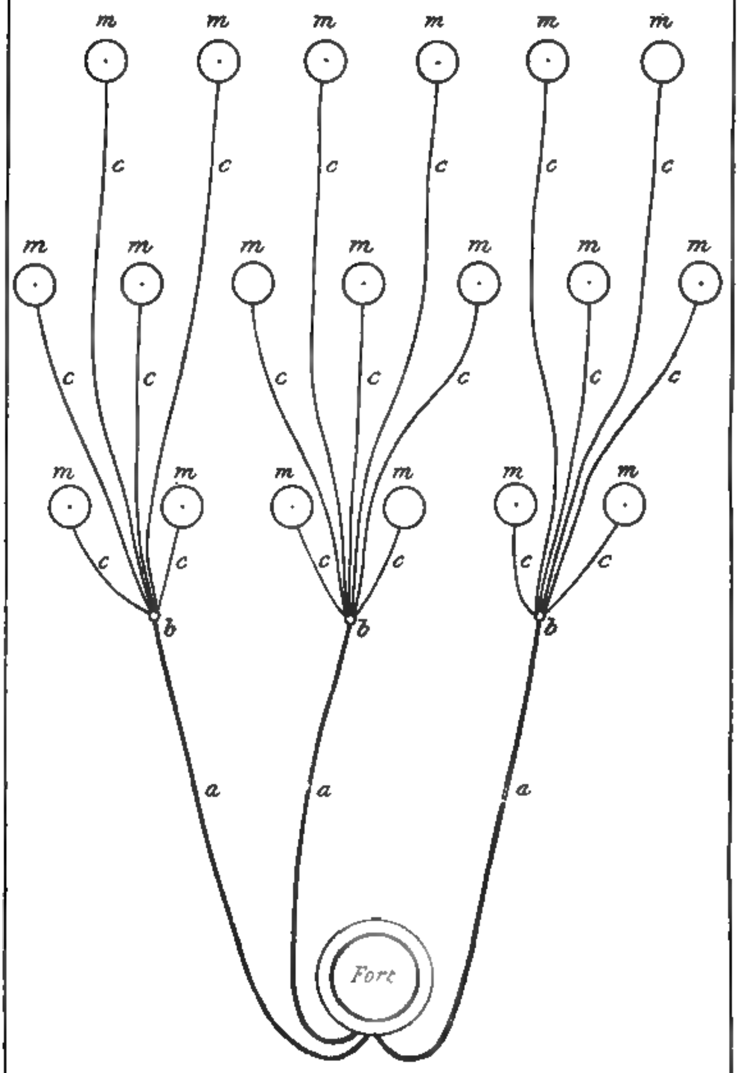
When all the mines with circuit closers, to be fired by observation, are in position, the submergence of the electro-contact mines may be commenced. This operation should be carried out as follows, and must always be conducted at slack water. One pinnace should be anchored at the end of the multiple cable, to which the core of that in connection with the series of electro-contact mines is to be attached, and should proceed to weigh the junction box. The other pinnace should be anchored at the point, where the outer extremity of the line of mines is to end. The large steamer, having received the mines on board, each connected to a sinker, and to the electric cable, as described at page 75, the attachments are completed, by means of the T connecting boxes, &c., with the main electric cable. The mines and sinkers are next hung over the side, in such a manner as to be readily cut adrift. The electric cables, from the disconnectors to the mines, should

be placed on the deck, across two spars rigged out over the stern to carry them clear of the taffrail. The main electric cable, should be placed forward: it should be arranged in flakes, to enable it to run out without much chance of kinking. When the steamer reaches the pinnace moored at the outer end of the line of mines, the end of the single core electric cable should be passed into her from the former and attached, temporarily, to one of the thwarts. The steamer should then proceed to place the mines in position, moving at the slowest possible speed, and steering for the pinnace or buoy marking the other end of the line. The mines should be dropped in succession, as soon as each disconnector is clear of the taffrail, which will occur as the main cable is gradually paid out. A testing battery and galvanometer should be kept in circuit during the whole operation, as it is impossible to test any individual mine, connected on this plan, after the whole have been placed in position. After the submersion of each mine, the end of the cable in the outer pinnace should be put to earth for an instant, to ascertain that the continuity is good. The galvanometer must be continuously and carefully watched during this operation. The accidental knocking of the mine against the side of the vessel when cut away, or the shock on striking the water may cause the rod in the circuit closer to make contact, but this unsteady deflection is readily distinguished from the steady deflection due to a fault in the insulation. Should the latter be observed immediately on the submersion of a mine, and before the end of the cable in the pinnace has been put to earth, it will shew that a defect exists, somewhere between that mine and the main cable. The position of this mine on the main cable should be noted, and as soon afterwards as an opportunity offers, it should be replaced by a good one. The test battery should still be kept on in laying the remainder of the mines; any fresh fault would then be shewn by an alteration in the deflection of the galvanometer. When all the mines of the group are placed in position, the end of the cable in the steamer should be taken to the pinnace containing the junction box, and connected with one core of the multiple cable, by the usual insulated joint. The other end of the cable in the pinnace may then be sealed with a tubing insulator, secured to a single cable connector, and lowered to the bottom, or it may be connected to a second cable laid out from another core of the multiple cable. When more than one line of electro-contact mines is used, the inner line should be laid first, and the cable of the outer lines brought round, outside and well clear of the flanks of those within them. When the lines have been laid, the buoys marking their position should be removed.

Electric cables carried round flank of mines.

The arrangement of the cables above described, is that in which the shortest possible length would be consumed, and would, perhaps, be the safest from discovery by an enemy's boats. In certain cases, however, it might be convenient to carry them by

ARRANGEMENT OF ELECTRIC CABLES.



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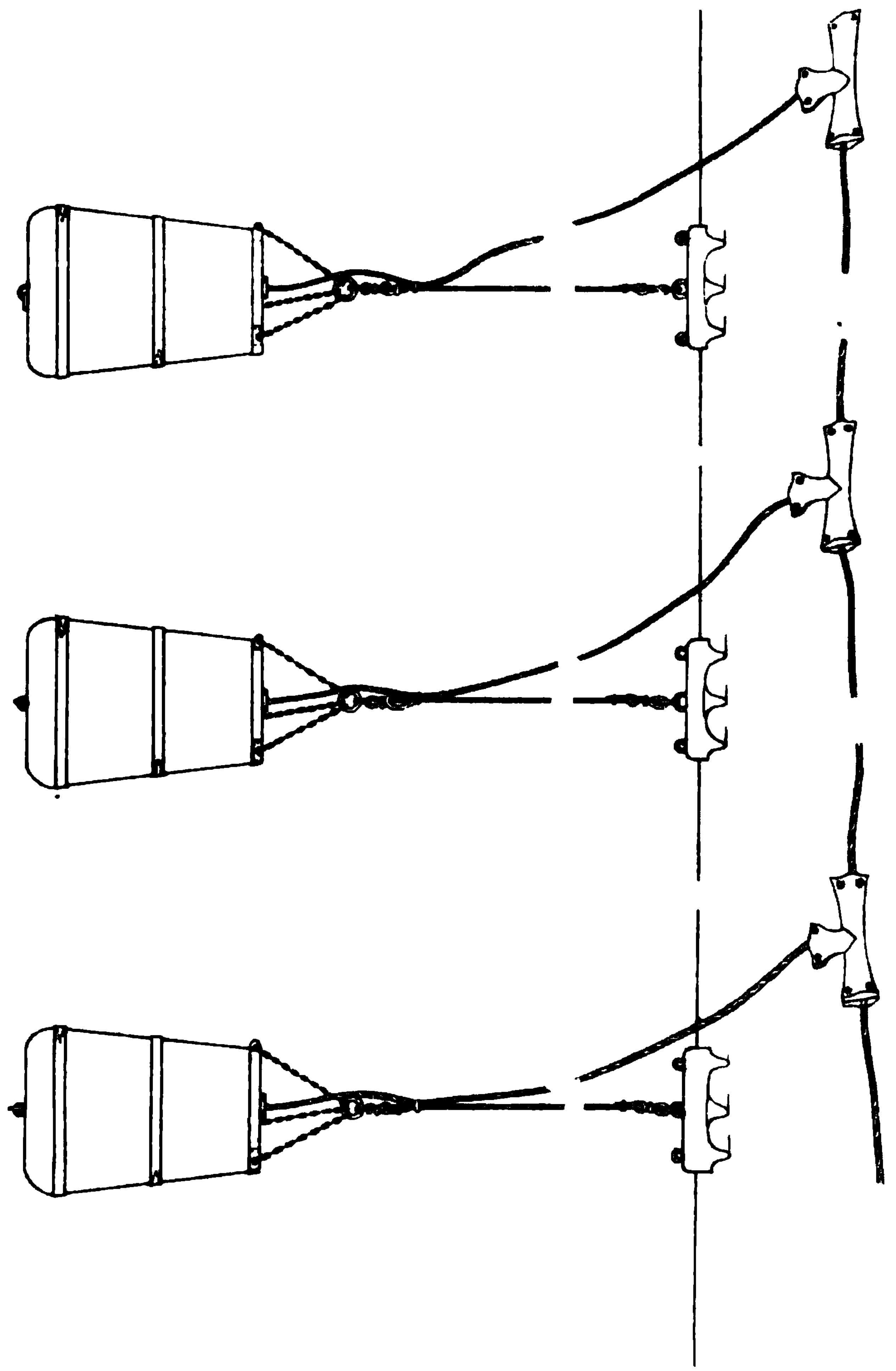
SERIES OF ELECTRO-CONTACT MINES.



Scale of 10 0 10 20 30 40 Inches

Lithographed at the S. M. E., Chatham.

B. Butler, Corpl. R. E.

a detour to the fort, as for example round the flank of the second and third line of mines, and there would be no difficulty in this, always bearing in mind that they should, in the first instance, be carried directly back for about 40 or 50 yards, so as to be safe from injury due to the explosion of their own line of mines, and that their subsequent course should be so arranged, as to keep them safe from damage from the explosion of any other mine in the system.

Cables to be protected from wash of sea.

In selecting any line to be taken, places where the cables would be subjected to a wash of the sea should be, as much as possible, avoided, and when it becomes necessary to place them in positions where they are necessarily subjected to the friction and rubbing consequent upon the motion of the water, special precautions must be employed for their preservation. In order to ensure this they are made with protecting armouring, as described at page 118 and shown in *Plate* XXX.

Position of electric cables to be concealed.

The Confederates used all sorts of devices to conceal their electrical cables, such as laying dummies, making considerable detours inland, &c., and such precautions must always be taken when required by peculiar circumstances. It is impossible, however, to lay down any rule for such contingencies, which must be left to the ingenuity of those in charge of the mines, who will be best able to judge of the capabilities of any particular position.

The only general rule which can be laid down, for guidance under such circumstances, is to place the cables where they can be subjected to the greatest amount of supervision, and where they can be most easily defended from injury by an enemy.

Arrangement of electric cables.

Plate LII shows the general arrangement of the electric cables and mines, when laid out in the manner approved by the Torpedo Committee. *a*, *a* are the multiple electric cables, connecting the fort with the junction boxes *b*, *b*; *c*, *c* are the single, electric cables, connecting the junction boxes *b*, *b*, with the mines *m*, *m*. Two of the cores of the electric cables, one on each flank, are reserved for electric telegraphic signalling.

Series of electro-contact mines.

Plate LIII shows the general arrangement of a series of electro-contact mines, attached by branches to a main cable. The details of the connections for this system have been already described at pages 75 and 159.

Protection of the mines from enemy's operations. Buoyant creepers proposed by Lt. Langdon, R. N.

To guard the mines from being grappled by the enemy, lines of protecting chain cables should be laid across the channel, outside, and extending beyond, the outer line of mines; and creepers, attached to sinkers, and buoyed so as to be off the ground, should be laid down at frequent irregular intervals in advance of each line of mines. The cables across the channel, would protect the mines and electric cables from being grappled by creeping, and the buoyed creepers would protect them from being grappled by sweeping. As an additional protection, and also as a means of deception, circuit closer jackets, with ends of electric cable

attached, should be moored at irregular intervals in advance of the lines of mines. The protecting chain cables should be as heavy as is consistent with convenience in handling. Chain cables of from 1-in., weighing 48 cwt. per 100 fathoms, to 1¼-in., weighing 75 cwt. per 100 fathoms, will answer the purpose. They should be laid in 100 fathom lengths. The large steamer should be used in laying out the chain cable, with a grapnel attached to one end and a sinker to the other, the cable being flaked on the afterpart of the deck, the end with the grapnel attached right aft and the other end forward. The steamer should move at the slowest possible speed, and great care will be necessary to prevent the cable taking charge, that is to say running out too rapidly, in paying out.

The creeper, for protection from sweeping, should be of 50lbs. weight, (or thereabouts), attached to a 7-cwt. sinker by means of a ⅝-inch chain, 3 feet long, and hooked into and lashed to the attachment chains of a circuit closer jacket, as shewn in *Plate* LIV. The creepers should not be attached to the protecting cable, but should be moored separately at irregular intervals.

These can be laid by the small steamers, or by the pinnaces.

Besides the mines arranged in a line, a few additional, in advance of the main body, would, as already stated, tend much to increase the security of the rest.

Stores and apparatus to be supplied to vessels and boats.

The stores required with the different vessels will be as follows:—

LARGE STEAMERS.

General Stores.—Buoys and rope, for buoying the ends of the multiple cable.

Spunyarn.

Lead and line.

Electrical Stores, for placing the electro-contact mines in position.

Test battery, 2 cells.

Detector Galvanometer.

Short lengths of insulated wire.

2 earth plates, with insulated wires attached.

Indian-rubber tubing.

" " tape.

" " solution.

Spanner for T connecting box } or shifting spanner.
" " disconnector }

Set of spanners for electro-contact mine.

Pliers.

Twine.

Knife.

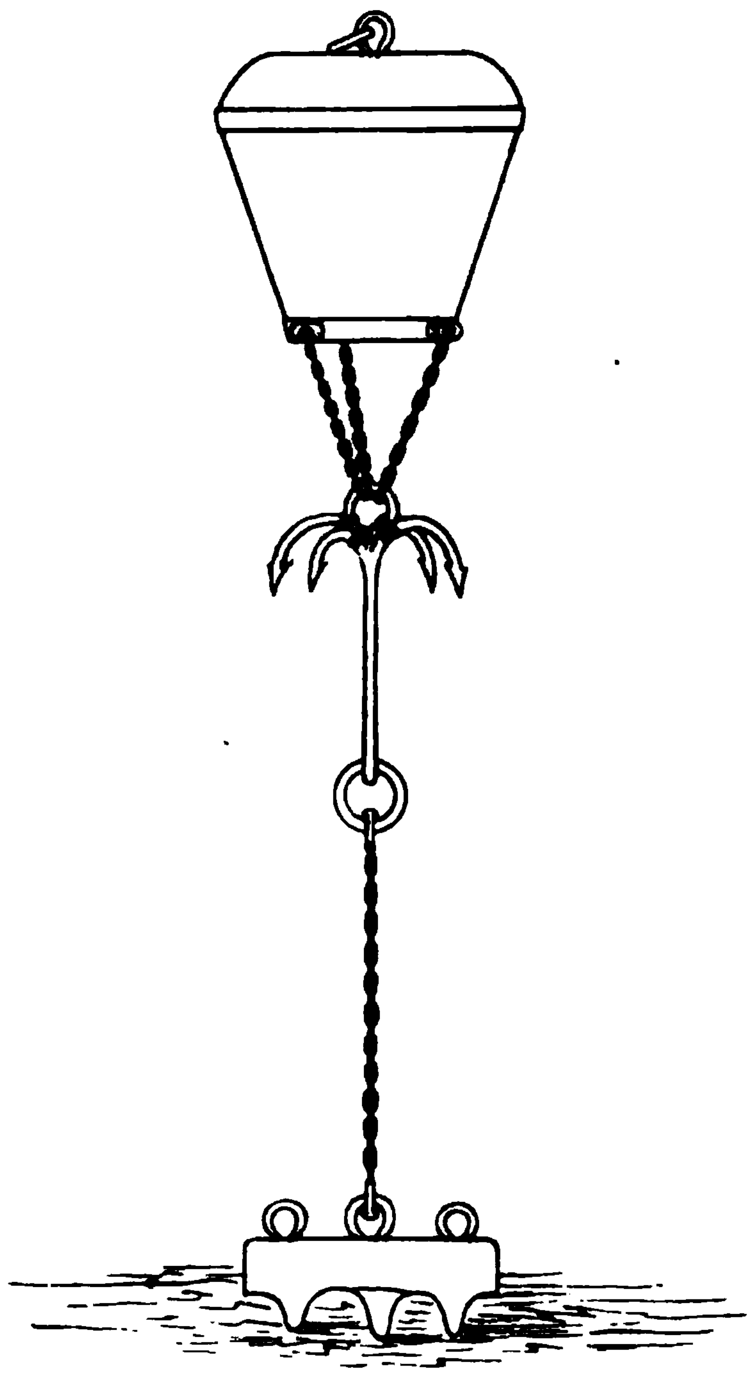
SMALL STEAMERS.

General Stores.—2 anchors and cablets.

PLATE LIV.

ARRANGEMENT OF CREEPER FOR

PROTECTING MINES.



Scale of 10 0 10 20 30 40 50 60 70 Inches

Lithographed at the S.M.E., Chatham. *B. Butler, Corpl. R.E.*

Lead and line.
2 marline spikes.
Slip-rope, of 3-inch rope, long enough to reach the bottom, at the greatest depth at high water.
Spun yarn.
Spare 2-inch rope, for general use.

ELECTRICAL STORES.
Indian-rubber tubing.
" " tape.
" " solution.
Pliers.
Twine.
Knife.
Shifting spanner.
Set of spanners for cases.
" " " circuit closers.
Wire for seizings.
2 earth plates (spare) one of zinc and one of carbon.
Spare shackles.
" earth plates, one zinc and one carbon, with insulated wire attached.
Tallow.
Pitch.
Luting (red and white lead).

PINNACES.

GENERAL STORES.—Junction boxes, with buoy ropes and circuit closer jackets attached.
2 anchors and cablets.
Spunyarn.

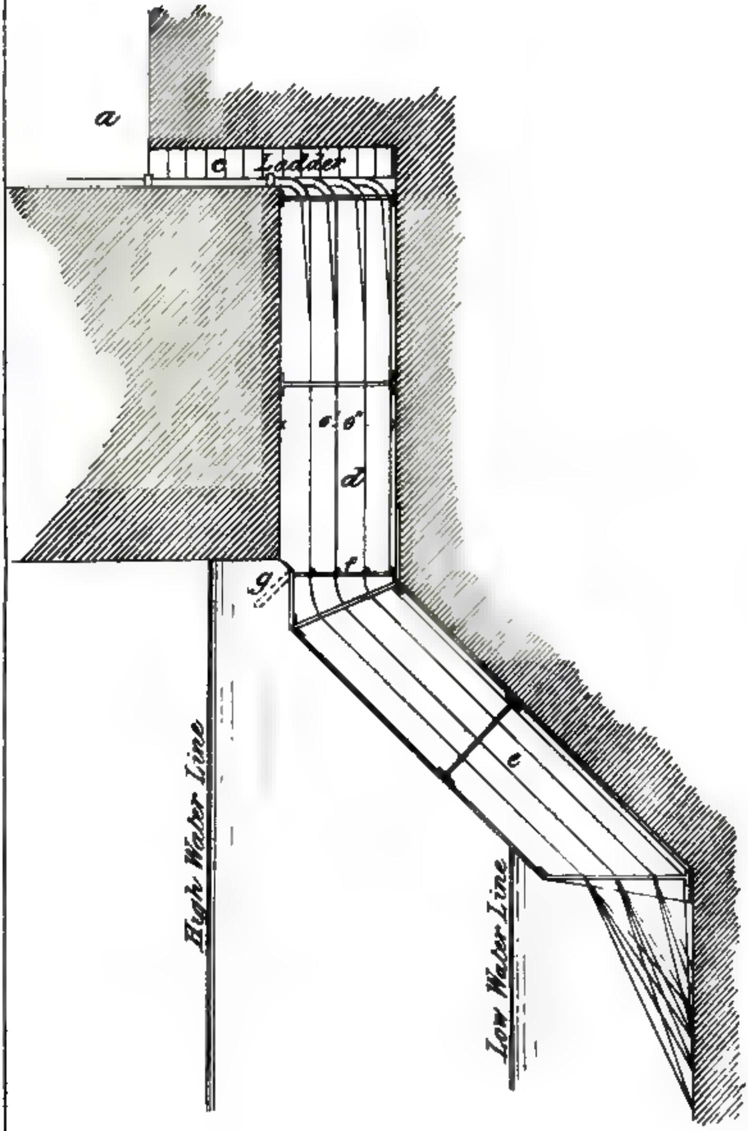
ELECTRICAL STORES.—Test battery, 2 cells.
Detector galvanometer.
Short lengths of insulated wire.
2 earth plates, with insulated wires attached.
Indian-rubber tubing.
" " tape.
" " solution.
Pliers.
Twine.
Knife.
Sounding telegraph instrument.
Spanner for junction box.

Introduction of electric cable into a fort.

The next point to be considered, is the best mode of introducing the cables into a fort or sea battery. In doing so, they should be protected to the utmost, not only from injury by an enemy, but from the friction and rubbing necessarily caused by the wash of the sea. Bearing these objects in view, advantage must be taken of local circumstances, which will present an endless variety of conditions, which must be met by expedients suited to the nature

PLATE LVI.

SECTION THROUGH CABLE CUT AND HOOD.



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secure the hood from the effects of an enemy's shot; *(f)* is a wrought iron diaphragm or shield, shown in detail in *Plate* LVII., through which each cable passes. This diaphragm need not be watertight, and is only intended to prevent the wash of the sea, rushing violently into the passage (*d*), and thence into the testing room, as would be the case without it in stormy weather. A man-hole (*g*) gives access to the hood, and permits the sea, rushing in through the hood and checked by the diaphragm *(f)*, to escape without bursting in the latter.

Frames to carry cables.

The multiple cables, on arrival at the foot of the hood, are carried in on a system of frames, *h*, *h*, *h*, shown in section in *Plate* LVIII. These are placed at intervals, along the hood and gallery, and are provided with four shelves or compartments, each carrying 10 cables, laid in a separate groove and numbered, making a total of 40 for the whole. As each multiple cable consists of 7 conductors, this would give a total of 280 conductors in all. These frames should be of gun metal; iron is too apt to oxidize, and wood, which would be alternately in water and air with every rise and fall of the tide, would be liable to rot and render constant repairs necessary. A bar (*i*), also of gun metal, fits over the top of each shelf or compartment, and when fastened down, keeps the cables in their places. The framework occupies a breadth of 2ft. 6in., leaving a space of 2ft. for access and examination of the cables. On arrival at the shaft (*c*) each multiple cable is carried up along the side of the shaft to the testing room, and each core attached to its respective binding screw, for connection with the instruments used in controlling the system of mines. Should it be required to carry more than 40 multiple cables into any particular fort, it would only be necessary to arrange more supports in each frame, for which there would be ample room. It is considered however that 40 multiple cables, or 280 single conductors, would be sufficient for all but very exceptional cases.

Level of floor of testing room and foot of hood.

The floor of the testing room should, if possible, not be less than three feet above high water spring tides, otherwise it would be very liable to be flooded by the wash of the sea in rough weather, for, even with the diaphragm *(f)*, there would still be a certain amount of motion in the water. Where possible, the outside of the hood should not be less than 10 feet below low water spring tides, because at such a depth, except on extraordinary occasions, there would be comparatively little motion from the wash of the sea.

To make connection with exterior.

The man-hole (*g*) gives access to the hood; for the manipulation of the cables, it would only be necessary to go in at low water and establish a communication with the exterior by pushing a buoy beyond the outside of the hood by means of a pole of sufficient length; the buoy, on floating to the surface, would carry a line with it, which would

be all that is necessary, and by it a cable might be hauled in or out as required. This would, in a great many cases, do away with the necessity of employing a diver, though it would nevertheless be necessary that a diver should be at hand, where any very extensive system of submarine mines may be used for defensive purposes.

Identity of each cable to be carefully preserved.

In passing from the outside to the testing room, the identity of each cable must be carefully preserved throughout, by means of a number, and each would be finally attached to a binding screw or connection similarly numbered, so that any particular one might be easily picked out if required. Much care would be necessary to prevent confusion, in carrying in the electric cables, in the first instance.

Diaphragm to cut for admission of cables into a fort.

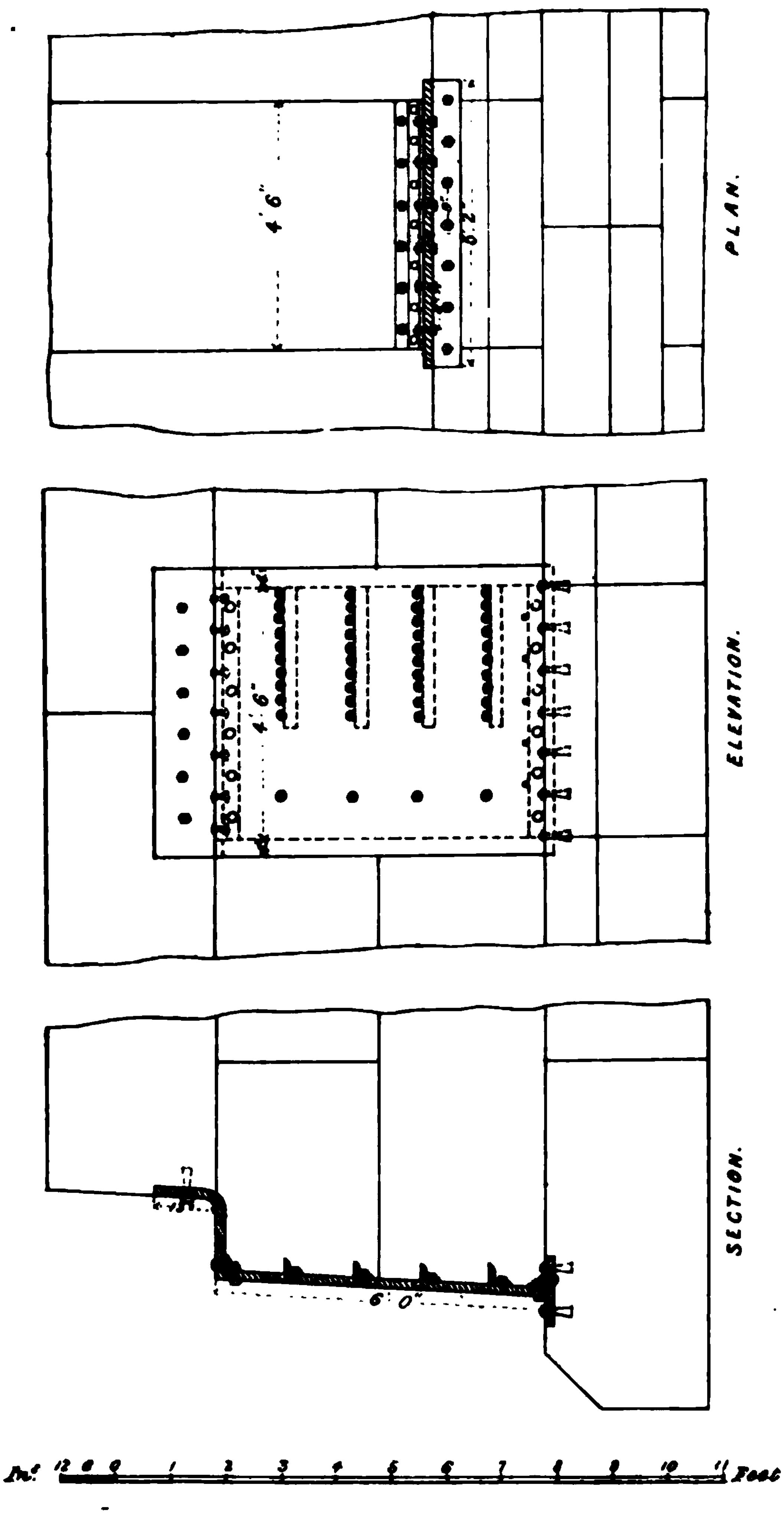
Plate LVII .gives a plan, elevation and section, of a design for a diaphragm or shield of the nature required at the point of *f*, *Plate* LVI. It need only be of sufficient strength to withstand the wash of the sea, being protected from an enemy's fire by the armour plating of the hood, which would, if necessary, be of the same thickness as that of the fort itself. It would, moreover, be on that side of the fort which would be least exposed to the enemy's fire.

The diaphragm is designed to be formed of the best 2-inch rolled iron plate, made to conform exactly to the external form of the masonry of the fort: to be supported at the top by a 2-inch wrought iron plate, bent to conform with the exterior of the upper course of masonry forming the sides of the external opening of the gallery, let into a recess in the exterior course of masonry forming the top of the gallery, and bolted securely to this latter. The foot of the diaphragm to rest on a 2-inch wrought iron plate, let into a recess in the exterior of the course of masonry forming the lower side of the opening, and bolted securely thereto. The whole of the plates, including the shields, to be equivalent in quality of metal to the best South Staffordshire iron. The diaphragm to be attached to the top and bottom supporting plates, by 3-inch angle irons, bolted to it and to the plates above-mentioned, as shown in *Plate* LVII. The sides of the diaphragm to be let into recesses cut in the courses of masonry, forming the sides of the exterior of the gallery.

Holes, $1\frac{1}{2}$ inches in diameter, to correspond with the rows of multiple cables to be carried into the fort, to be drilled through the diaphragm, and 3-inch angle irons to be attached to the inner side of the diaphragm, below each row of holes, to support the electric cables on entering the gallery. The edges of the holes to be rounded off so as to prevent injury to the electric cables, and the latter to be gripped inside the shield by clutches for each, secured to the angle irons by bolts and nuts.

A series of 2-inch holes to be drilled through the diaphragm, opposite the passage, and a few $\frac{1}{2}$-inch holes, just above the lower

DIAPHRAGM TO CABLE CUT.



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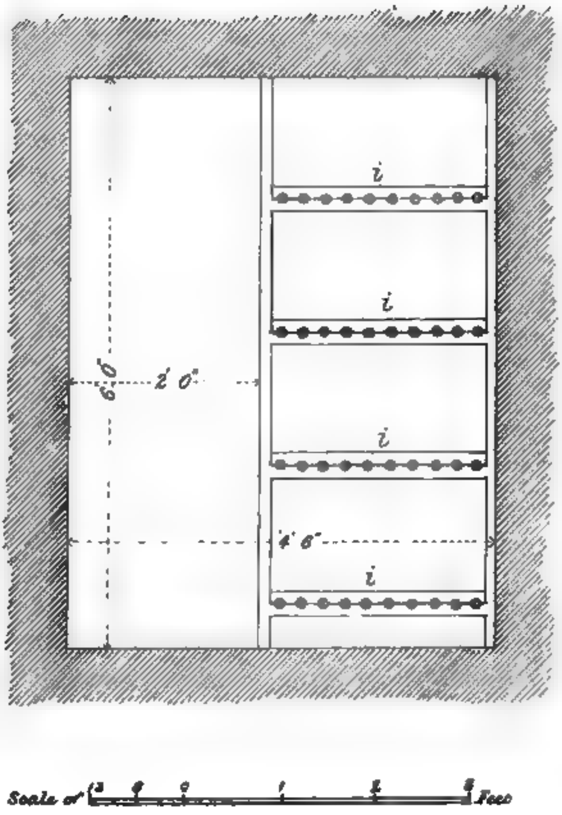
FRAMES TO CARRY CABLES
THROUGH GALLERY INTO FORT.



Lithographed at the S M E Chatham

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angle iron, to allow the water to pass freely in and out according to the state of the tide.

The iron plates have, in all cases, been designed to conform exactly to the shape of the external masonry of the fort, in consequence of the well known effect of the sea in loosening stones or other objects, slightly projecting from any structure, exposed to the action of waves.

General arrangements of testing room.

The general arrrangements of the testing room are dependant on the nature of the means provided for firing the mines, and on the situation of that room within the fort or defensive position in which the work is carried on. The mines may be arranged to be fired by means of circuit closers, with the alternative of firing at will by intersections, or they may be disposed to be fired by the former method only, making them purely self-acting. In the testing room shown in *Plate* LV., which is supposed to be situated in the lower casemates of an iron-plated fort, similar to those defending Spithead, it would, of course, be impossible to arrange for a combination of the self-acting mode of firing, and the method by intersections in the same room. In other situations, on the contrary, the combined system may be advantageously employed, where circumstances are favourable for its adoption.

Introduction of multiple cables into a fort.

Where there is deep water all round a fort, as in the case shown in *Plate* LV., the multiple cables may be at once passed into the hood, with comparatively little difficulty. Where the water is shallow, they must be taken on shore, one by one, in small boats, from the steamer from which the $\frac{1}{2}$-knot lengths are payed out, the spot chosen for landing the cables, should, if possible, always be towards the rear of the fort or observing station to which they belong, it should moreover be as sheltered as possible from the breakers or shifting shingle, and from the fire and operations of the enemy.

The cables should be landed at the top of the tide, and sufficient slack coiled above high water mark to reach into the fort or observing station. At low water they should be conveniently disposed, along the sand, mud, or shingle, and snugly deposited in one or more little trenches dug for the purpose, and then carefully covered in and concealed. There would probably seldom be more than seven multiple cables in each group. The same precautions should be observed above high water mark as below, as regards burying them in trenches and concealing them to the utmost extent. The ends are next brought into the testing room, and strongly secured by staples to the interior face of one of the walls of the room, always bearing in mind that, where firing by observation is to be practised, the wall looking seaward should be kept exclusively for the observing arcs. The armouring of each cable should then be stripped for about 18in., the protecting wires turned back and cut off, and the sharp ends

bound over with spun yarn, to form a turk's head, in the usual way.

Connection of electric cables to testing and firing apparatus.

To form the connections with the the testing and firing circuits, brass double terminals, mounted on wooden brackets, are screwed into the face of the wall, in sets of sevens, horizontally. Each terminal is numbered, and each of the seven cores of the multiple cables is led to its corresponding terminal on the bracket, as indicated by the numbers, and finally connected there.

The points of connection should be five or six feet from the ground, or at such a height that they can be readily and easily examined. The multiple cable and its protecting wires should not be encased in a troughing, but well exposed to view, so that any part of the arrangements can be easily got at when required.

It is most desirable, that no joint or break should exist in the circuit, between the multiple cable in the sea and the double terminals in the test room, so that when any fault occurs, this part of the circuit may be thoroughly relied upon. Much trouble may be avoided by attention to this very simple matter. Shelves, similar to those of a bookcase, should be fixed on brackets in the face of the wall, to which the multiple cables are led, and these shelves should be so disposed, in four rows, as to give ample room for the shutter signalling apparatus and signalling batteries. The multiple cables should be led up the side of the signalling boxes, and short electrical connections should be made from the double terminals to the corresponding line terminals, as indicated by the numbers, on the top of the signalling boxes. With a test table 3′ 6″ high in the middle of the wall, four boxes of shutter signalling apparatus might be conveniently disposed in two rows, two boxes on the left and two on the right hand side of the test table. Under each shelf of shutter signalling apparatus, should be the signalling batteries belonging thereto, by which arrangement the connecting wires, between the cells and the battery terminals of the shutter signalling apparatus, may be made very short and unlikely to cause confusion.

Attachment of shutter signalling apparatus.

The signalling battery provided, for a set of seven mines, consists of 14 Daniell's cells, arranged in rows of two under each shutter signalling box.

When the circuits to the submerged mines are in good working order and well insulated, and of approximately equal electrical resistances, it has been found convenient to connect the 14 cells in two sets of seven, that is to say, to connect seven coppers together, and seven zincs similarly combined to the remaining seven coppers, and finally the remaining seven zincs together, to form the other pole of the battery, thus producing two cells of large metallic surface. In working with this combination, the battery terminals, at the front of the shutter box, should be connected together by a piece of insulated wire running along the

front of the box, with the gutta percha stripped at the points where it is gripped by the successive battery terminals. This wire should then be connected to the zinc pole of the combined battery cells beneath, and the copper pole connected to earth. The battery current, in circulating, would then divide itself through each of the signalling coils and thence to the submerged mines. This arrangement facilitates the testing of the signalling batteries, as the 14 cells can thus be tested in one circuit*. Should any circuit become deficient in insulation, and thus deprive the remainder of the group of their proper share of the signalling current, it will only be necessary to detach two of the Daniell's cells from the combined battery, and to place them on the faulty circuit, also detaching the latter from the wire that had previously connected all the battery terminals. A circuit with a considerable fault may, in this way, be made to work efficiently, by giving it a separate battery and connections, provided it is not so defective as to be utterly untrustworthy. Paper numbers, to correspond with the numbers of the mines, should be gummed to the shutter levers and to the ivory tablets on the top of the boxes, to identify each circuit.

Test table.

The test table should be placed below and between the shelves carrying the shutter signalling boxes and batteries. It consists of a board of 1-in. deal, framed and well planed, about 3ft. 6in. by 2ft. 8in., supported at the corners on four dwarf legs, 4in. high, and turned in a lathe. It should be placed on an ordinary table, strongly made to prevent unnecessary shaking. The switch plates should be let into the test table so that their surface should be flush therewith. The details of the test table shall be explained hereafter. As these switch plates are principally for connection with different earth plates, the proposed arrrangement of these latter must now be described.

The following earth plates should be placed in the sea:—

Earth plates

1st. A copper earth plate for testing, consisting of a piece of sheet copper of No. 10, B.W.G., 5in. by 6in.

2nd. A piece of rolled zinc for testing, ¼in. thick, 5in. by 6in.

3rd. A piece of zinc, to serve as an earth plate for the signalling batteries, size, 5in. by 6in., by ¼in. thick.

4th. A piece of zinc, of the same size, for a common earth.

5th. A piece of zinc, of the same size, to serve as an earth for the firing battery.

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* A special large Daniell cell, combining, in each pair of plates, the surface obtained by connecting the two sets of seven, has been suggested for use with the shutter signalling apparatus. Two such cells would answer perfectly if the system of mines were in good order, and be more convenient for work than the combination now employed. Should any circuit become defective, it could equally be detached and supplied with a separate battery, as above described.

6th. A piece of zinc, of the same size, to serve as a second earth for testing the firing battery.

Box to contain earth plates.

In order that these earth plates may be protected from injury as much as possible, they should be placed in grooves in a wooden box specially made to hold them, and a piece of 7 cored multiple cable, in which the different cores at each end have been identified and numbered, should be led into the box at one end and gripped with a nipping hook, as in the junction box, to prevent motion. The connections, between the conductors and the earth plates, should be very carefully made and the soldered joints well covered with pitch, as already described. The spare core of the multiple cable, should be connected to a zinc plate of the dimensions given, which could be used if any of the other test zincs became faulty. The box containing the earth plates, should be placed so as to be covered by the sea at low water spring tides, but nevertheless accessible. This box should be weighted with stones to keep it steady, and perforated with holes, to allow free access for the water. The piece of multiple cable, connecting the earth plates, may be arranged in the same trench as the multiple cables to the mines, and led into the test room in the same manner as the other cables. On reaching the testing room, the armouring should be stripped from a sufficient length of its inner extremity, to allow the cores to be led, from the back, under the test table and through small auger holes in that table, to their corresponding switch plates, where the conductor should be firmly and permanently connected to the binding screw at one corner of the plate. The core leading to the spare zinc earth plate, would remain unappropriated until required,

Arrangement of earth plates in the testing room, suggested by Mr. Brown.

At the suggestion of Mr. Brown, Assistant Chemist to the War Department, a trial has been made by using a series of earth plates in a bucket filled with sea water placed in the testing room. He is of opinion that, if the water in the bucket is put in connection with the water of the sea, by means of a conducting wire, terminating at one end with a zinc plate, in the bucket, and at the other with a zinc plate, in the sea, the tests made with the different earth plates in the bucket, will be identical with those made with corresponding earths placed absolutely in the sea. This arrangement is very convenient, admitting of the use of some additional earth plates, such as tin and carbon, with which the condition of the circuit in a submerged mine may be tested. The arrangement adds resistance to the circuit which does not, however, materially affect the readings on the astatic galvanometer. There is an appreciable difference when the readings are taken, with earth plates arranged in this manner, on the 10 ohm and the 2 ohm coils of the 3 coil galvanometer. It is consequently recommended that the earth plates used in the daily register of tests, to be hereafter explained, should be those in direct communication with the sea.

When the system of firing by intersection is employed, the telescopic firing arcs should always be placed on the side of the room looking towards the sea. *Arrangement of firing arcs.*

The main groups of mines would generally be placed in three rows, the lines of which are arranged to converge on a distant observing station, and the principal observing station, to which the multiple cables are brought, should be as nearly as possible at right angles to the direction of the line of mines, and must consequently be placed well to the rear of those mines. It will be convenient to designate this latter station as the firing station, and the former as the converging station.

Where the number of mines in a row does not exceed 10, one observing arc will suffice for each line, sights giving the alignments to each individual mine, are firmly fixed on each arc, as shall be hereafter described. In no case should the alignments of mines belonging to two different rows, be taken on the same observing arc. The observing arcs may be conveniently set up on firmly fixed tables, 4′ above the ground, with a clear view of the scene of operations through long and flat openings in the wall, somewhat in the form of horizontal loop-holes, specially so made as to be as little conspicuous as possible. Each observing arc at the firing station, requires its own observer, and the arcs should be placed with a clear interval between them of not less than 4 feet. At the converging station, one alignment and a much simpler form of observing apparatus is required for each row of mines, an observer being, however, necessary for each line. A single fixed telescope and firing key, is all that is required, a simple arrangement, by which the axis of the telescope may be put on the alignment of the mines, and held there without danger of moving being provided. A four cored cable connects the observing and firing stations. If the two stations are separated by land, a four cored unarmoured cable, as shown in *Plate* XXX., *Fig.* 3, buried in the ground, will be required; if by water, a four cored armoured cable, as shewn in *Plate* XXX., *Fig.* 4, must be used.

The details of the construction and connections of the firing arcs shall be described hereafter. For the present it is only necessary to remark that, for each alignment, at both stations an arrangement is provided at the observing arc, forming a break in the circuit, these can be bridged over simultaneously at pleasure, by the depression of the corresponding contact keys at the two stations. At the firing station, the whole of one set of contacts, belonging say to the inner row of mines, are led, through the connections of the shutter apparatus, signalling battery, &c., to No. 1 core of the four cored, multiple cable, with a series of firing keys in circuit to form the breaks; the other end of No. 1 core, at the converging station, is led to one contact of the key belonging to the corresponding line of mines, the other contact of the key being connected to a zinc earth plate in the *Connections of firing arcs for use.*

sea. The whole of one set of contacts belonging to the middle row of mines, at the firing station, are similarly connected to No. 2 core of the four cored, multiple cable, and thence to one contact of the key, belonging to the middle alignment, at the converging station. One set of contacts of the outer row, are similarly led from the firing station to No. 3 core, and so on to the converging station.

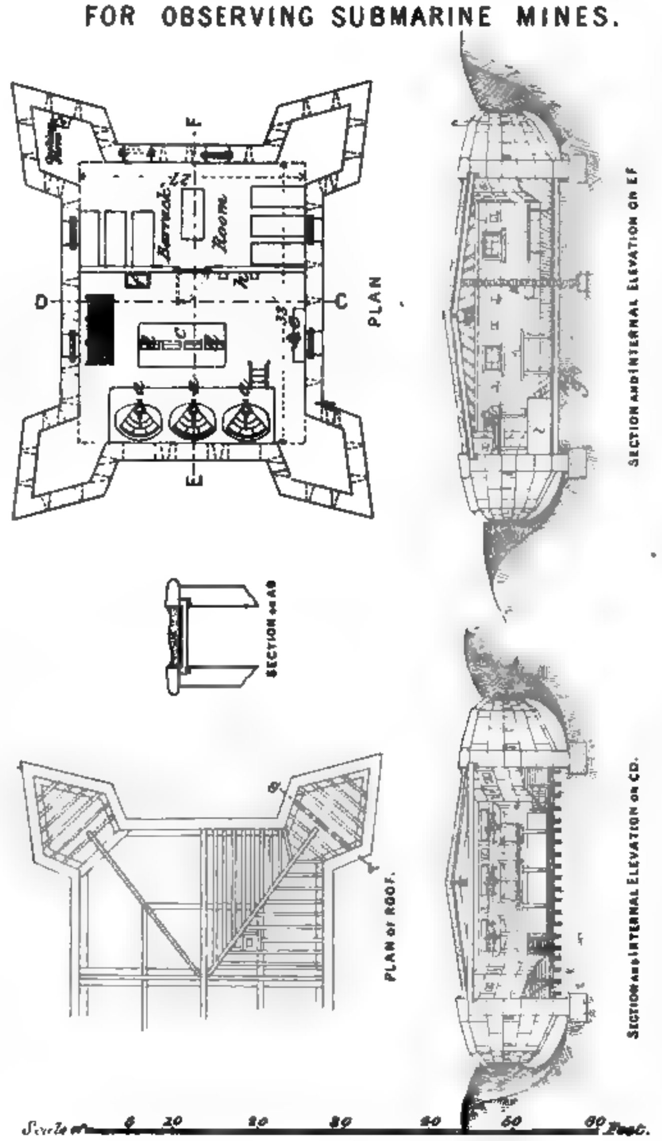
Mode of action of the combination.

By this arrangement, when a ship is observed to be over a mine, the corresponding keys at both stations are depressed simultaneously, and the signalling battery circuit closed through that particular branch of the system; the shutter, corresponding to the mine over which the ship is passing, falls; the firing battery is automatically thrown into circuit, and that particular mine is fired. Simultaneously with the falling of the shutter, the connection that was made through the firing keys, used in combination with the observing arcs, is cut off. The observers, in point of fact, perform the same operation on the shutter signalling apparatus, as the ship would do if she struck the circuit closer. In both cases, an earth connection would be momentarily made for the signalling battery, through some one particular coil in the shutter signalling apparatus, and that shutter would fall. In this way, firing by judgment is made supplemental to, and not in lieu of, firing by contact, and the mine has a double chance of being fired at the right moment. No inattention on the part of the observer at the critical moment, would prevent the mine being fired, if the ship struck the circuit closer.

Electric telegraph between stations.

The fourth and remaining core of the 4 cored cable, connecting the two observing stations, is used for telegraph purposes. A recording instrument, and a telegraphist, are at each station, and timely notice is given, from the converging station, to the observers at the firing station, of the particular ship most advanced in the attack. As the ships will be clearly seen for a certain period before they are over the mines, there will be time for the two telegraphists to identify each ship by some peculiarity, in the hull, funnel, or rigging, and to warn the observers which ship is foremost, &c. For instance, a message might be sent, from the converging station, "Flag ship near outer row." On receiving such a signal, the observer at the firing station, in charge of the outer row, watches accordingly. When the ship is passing the alignment of the outer row of mines, the telegraphist at the converging station signals a long dash, which deflects the galvanoscope, on both the recording instruments, and the signal is continued, till the ship has passed over the outer row. The observer, at the firing station of the outer row, is thus informed that the ship has passed his line, and the observer of the middle row is then warned that the "flag ship" is approaching his line, and so on to the third row, if the ship should get so far. When a squadron of vessels advances in

DESIGN FOR A DEFENSIBLE STATION, FOR OBSERVING SUBMARINE MINES.



Lithographed at the S.M.E. Chatham.

B. Butler, Corp^l R.E.

échelon, and separated from each other by only a very short distance, it will be necessary for the observers to confine their attention to one or two of the largest, or most conspicuous, vessels, to limit the risk, as much as possible, of the two observers, at the firing and convergent stations, in charge of the same line of mines, simultaneously watching two different vessels, in which case the wrong mine might be fired.* Other combinations, to be hereafter described, may also be made, to suit different conditions, for firing a system of mines by intersections. In all cases, however, the arrangements are so made that, in the event of the observing station being captured by an enemy, the mines would still be capable of being fired by the self-acting system, circuit closers being attached to each for that purpose.

When the testing room is in such a position as to preclude the firing arcs being placed therein, as, for example, when it is situated in the lower tier of casemates of an iron-plated fort, as shewn in *Plate* LV., separate arrangements for firing by intersection must be employed, when this mode of action is adopted.

Defensive observing station.

In certain cases, it may be requisite to establish a firing or observing station in a detached position, at some little distance from a fort. When this is necessary, it should be fortified, to ensure its safety from a sudden attack, "de vive force." Such a building should be solidly built, with a ditch effectively flanked by musketry. It should be well covered by earthen blindages, and be concealed to the utmost extent, compatible with its use as an observing station, from view from the direction in which an enemy would attack. In addition to the testing room, it should contain a barrack room for the accommodation of the observers and electricians, so that they might be always on the spot for work. *Plate* LIX. shows a general design of such a building. *a*, *a*, *a*, are the observing arcs; *b*, the firing battery of 150 cells; *c*, the testing table; *d*, the shutter signalling apparatus; *e*, the working bench; *f*, the sink; *g*, the opening for the introduction of the electric cables; *h*, the fireplace; and *i*, a cupboard, below the platform, on which latter the observers would stand to work the firing arcs.

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* The Austrians formerly used the camera obscura, for determining the position of a vessel, in connection with a system of firing submarine mines at will. They do not seem to have found it sufficiently accurate for the purpose, and have, consequently, given it up. Where sufficient height, to enable such an instrument to be employed to advantage, is available, it might, however, possibly be used, in combination with a telescopic firing arc. In such a combination, the camera obscura would indicate the position of a ship, while the telescopic firing arc would determine the proper moment for firing the mine with accuracy. It is perfectly certain that extreme care and very well practised men, are essential to the success of the system of firing by intersections above described.

Disadvantage of arrangement of mines in lines.

The arrangement of a system of submarine mines in lines, possesses one serious disadvantage, viz., that an enemy, having once ascertained the position of one mine of a line, either by its explosion, or by any other accidental circumstance, would know, within limits, where the others were to be looked for. In order to obviate this disadvantage, it would always be necessary to scatter a few mines at irregular intervals in front of the advanced line—to put them, so to speak, in the position of skirmishers, and to place some, in irregular positions, in rear also, retaining the line formation for the main defence. These mines, in advance and in rear of the lines, might either be simply electro-self-acting, or arranged for ignition on the same principle as those of the main system as circumstances required.

Mode of obviating the same by placing advanced mines at irregular intervals.

The first object of an enemy would be to clear a passage of sufficient width, through the system, to enable him to pass freely in, and for this purpose he might employ drifters, with or without dragging grapnels, for the purpose of either firing some of the charges by striking the circuit closers, or grappling and destroying the electric cables and other gear. These drifters might be boats, allowed to float in with the tide or wind, and need not necessarily contain any men, so that the loss of human life would not be a certain consequence of their destruction by the explosion of a mine. In order to stop such a system of attack, light booms or strong fishing nets would no doubt be extremely useful, and should be employed wherever circumstances admitted. To stop drifters with dragging grapnels, it would seem to be a good plan to lay three or four heavy chain cables, at intervals across the channel, in advance of any system of mines. The grapnels would catch in these, and the weight of the chains would be sufficient to bring up the drifters before arriving at the system of mines.

Defence of mines from drifters.

Defence from dragging grapnels.

Defence by heavy mooring chains.

Mines must be watched at night.

The night would unquestionably be the safest time for an enemy to carry on operations of this nature, and it would be necessary to employ boats to row guard, in order to watch his proceedings. The mode of communication with these boats is a matter of considerable importance, and some means of rapidly transmitting intelligence is absolutely necessary. This can, of course, be done by the army and navy system of flashing signals, but the lights, under certain circumstances, might be a disadvantage, as they would indicate the position of the guard boat. In order to obviate this, a system has been devised, by which a boat rowing guard can be put in electric telegraphic communication with a fort or guard ship, by simply paying out an insulated wire, attached to a telegraph instrument in the fort or guard ship, and carrying a second telegraph instrument on board the boat, or one or more of the lines of the multiple cables, connected with the system of mines, may be used for this purpose, an electrical connection being preserved with it by carrying

Electrical system of communication between a fort or ship and guard boat.

an insulated cable up from the junction box to the buoy marking its position, sufficient slack being left to allow of its being brought into a boat and connected with a telegraph instrument to work from the latter. The system is so arranged that no electrical batteries need be carried in the boat, the whole of them being retained at the Head Quarter Telegraph Station. The instrument in the boat would be a simple Morse sounder, so that no light of any sort would be required to read the message. The telegraph instrument at the Head Quarter Station might either be a Morse sounder or a Morse recording instrument, and, when the latter is used, the system may be so arranged that all messages, both those emanating from the Head Quarter Station and those received from the boat, may be recorded for future reference. By this means messages can be transmitted either by the Morse Telegraph Alphabet or by any signal code, and, when the latter is employed, any man who has been taught the army and navy system of signalling, can learn to use these instruments with very little practice. The apparatus has been used for some time in the river Medway, and at the Nore, in carrying on our submarine mining operations, and answers perfectly. Should the guard boat be chased, it would be only necessary to detach the electric cable from the telegraph instrument and throw it overboard, with or without a buoy and line attached to it, and pull away. It could be recovered at leisure, by underrunning it from the shore end, if a buoy were not used.

Morse recording telegraph instruments.

In order that telegraphic communication may be maintained between the observing stations, a Morse recording instrument is provided for each. These instruments are of the Post Office pattern, and are fitted with a galvanoscope to indicate when a current is circulating: this is substituted for the ordinary galvanometer with glass cover, which is not always serviceable. The coils of the instrument, including the galvanoscope, have a resistance of 600 units, and the messages can be received by sound as well as recorded on the tape. A separate winder is provided for receiving the tape after the message has been impressed on it. A mahogany cover protects the instrument from dust and accidental injury, when not in use. It will be sufficient to provide 10 cells of Daniell or 10 cells of Le Clanché, at each station, with the instrument, and an equal number of cells in reserve.

Morse sounding telegraph instruments.

Portable sounders are provided, to communicate by telegraph between the observing station on shore and the working parties in the boats. These instruments have a resistance of 600 units, and are equally available for correspondence with the Morse Recorder adopted for this service. They would, however, generally be used in pairs, and in order to avoid the necessity of carrying a battery in the boat, it will be found convenient to work them with a continuous current. For this purpose, the instruments should be adjusted to the same degree of sensitive-

ness, before leaving the office. They should be tried by putting 10 Daniell's cells in connection with them with a closed circuit, using sea earths for the return current: in this way, if the battery is too weak, or the springs are not adjusted correctly, the signals will not be satisfactory and the fault can be at once rectified. This will often save time, as when out in the boat these adjustments frequently cause delay.

Connections for work.

For work, the instrument at the shore station is arranged with one pole of the battery connected to the terminal (Z) or (E), and the line to its own (L) terminal, the other pole of the battery being to earth in the sea. The instrument in the boat, is arranged with the line connected to its own (L) terminal, and an earth plate in the sea to zinc or (E). Both armatures are then attracted, as the battery current circulates continuously through both instruments; when the key at either instrument is depressed the electrical circuit is broken, and both armatures would fall back. When using these instruments in pairs, as above described, it has been found advisable to reverse the connections of the battery each day, so that the cores of the instruments may not become permanently magnetized. There is always a certain amount of residual magnetism in using these instruments with a closed circuit, for this reason the signals must be sent slowly and distinctly, or letters may occasionally be slipped and the signals become confused.

Visual signalling apparatus.

The working parties in the boats, should have the means of communicating with each other and with the observing stations on shore, by means of visual signals.

Flags.

For day signalling, hand flags are required, and these, with their staves, can generally be made on the spot. Two sizes of hand flags have been approved, one for short distances and for practice, and the other for signalling over distances exceeding one mile. The color of the flags should be dark blue and white, the seam being horizontally across the centre of the flag. The small flag should be 2ft. 6in. × 2ft. 6in., with a staff 4ft. 6in. long. The large flag should be 4ft. × 4ft., with a staff 6ft. 7in. long. Every opportunity should be taken of practising the men in visual signalling, as the operations in laying out or examining the mines are much facilitated by a ready means of communication between the working parties.

Night signalling apparatus.

For night signalling, special apparatus is necessary, and each observing station should be supplied with the means of communicating with a working boat or friendly vessel outside, by means of Walker's oxy-calcium light.

Walker's oxy-calcium signalling lamp.

This apparatus should be supplied in duplicate sets. Each set consists of 1 lamp, 2 retorts for making the oxygen gas, 2 gas bags, 1 pressure bag, 1 wash bottle, and 1 pair of trimming scissors.

The oxygen gas must be prepared beforehand and collected in

the gas bags, and two bags full of gas have been found sufficient to carry on signalling continuously for 3 or 4 hours.

As the distances, to which signals are required to be sent, seldom exceed 3 or 4 miles, the gas may be diluted with its own volume of air; at one distillation, which takes about ten minutes, enough gas may be produced to fill half the capacity of each bag: common air may then be pumped into the bags with a pair of ordinary bellows, till the bags are quite full.

The following is the best mode of preparing the gas and using the oxy-calcium light. The light is obtained by causing a jet of oxygen to pass through the centre of a spirit flame, and to impinge upon a cylinder of quick lime placed therein.

Construction of lamp.

The lamp is composed of the following parts, viz:—

1st. Spirit chamber and burner.
2nd. Oxygen conducting pipes.
3rd. Lime holder.
4th. Disc with key, for signalling.
5th. Lens, arranged for emittting parallel rays of light.

To trim the lamp, fit the burner with pieces of round cotton wick, about 6" long, and of sufficient thickness to fill the wick holders without being either too tight, or too loose. The wick should be cut level with top of the oxygen pipe. Fill the spirit chamber with spirits of wine. During the trimming process, the spirit chamber is detached from the body of the lamp, by unscrewing the knobs at the bottom, and replaced when ready for work. The oxygen conducting pipe passes up through the centre of the burner, at an angle, from the perpendicular, of about 15 degrees, and, in attaching the spirit chamber to the body of the lamp, the pipe must incline towards the lime holder, This is done by noting the side of the lamp on which the tap of the oxygen pipe should be placed.

To make the oxygen gas.

The oxygen gas is obtained from a mixture of chlorate of potash and peroxide of manganese in the following proportions, (by weight), viz.:

When using an iron retort,*	4 of chorate of potash and 1 of peroxide of manganese.
" " copper "	6 of chlorate of potash and 1 of peroxide of manganese.

To make the gas, put about ½ lb. of the above mixture in the retort and place it on a fire, having previously screwed the cap tightly home.† Before placing the retort on the fire, the gas

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* Iron retorts are not recommended when copper can be obtained. They are not so easily repaired: a new bottom may always be put in a copper retort, whereas the iron, being cast, is almost irreparable, when once worn through. Copper retorts have been approved and sealed, to govern the supply of stores for service.

† The retort must be carefully watched during the process of making gas, and should the latter appear to be produced too quickly, the retort

bag should be connected, by means of a piece of indian-rubber tubing, to that part of the wash bottle marked "*out*," and a separate piece of tubing attached to that part of the wash bottle marked "*in*." One end of the piece of tubing, which is attached to the part marked "*in*," is held in the hand, and as soon as the gas begins to come, it is connected to the iron tube of the retort. The gas will now pass through the wash bottle to the bag. Shortly after the retort has been placed on the fire, steam will be given off, but it is easily distinguishable from the oxygen by holding a piece of burning wood, (without flame), to the tube of the retort when, if oxygen is passing, a brilliant white flame will be produced. The wash bottle should be about half full of cold water. Half a pound of the mixture will fill one bag; if mixed with common air this will be sufficient for two bags. The gas should not be mixed with air when the distance to be signalled is more than five miles.

Storage of gas bags.

When in store, the gas bags should always be kept filled with air. The indian-rubber of these bags is liable to become oxidized if any residuum of gas remains within them, and unless this precaution is taken they soon deteriorate.

To obtain the light.—

1st. Light the spirit lamp.
2nd. Place a lime cylinder, 1 inch long, in the lime holder.
3rd. Connect the gas bag, by a piece of indian-rubber tubing, to the oxygen tap at the side of the lamp.
4th. Open the tap of the gas bag.
5th. Place the canvas pressure bag, (containing about 10 or 12 lbs. of sand or dry earth), on the top of gas bag.
6th. Turn on the tap at the lamp and adjust the lime cylinder, by moving the holder backwards or forwards, till the oxygen jet impinges on the end of the lime, and regulate the oxygen tap, till just sufficient oxygen passes through to render the end of the lime incandescent.

Hand signalling lamps.

For short distances, and for practice, hand signalling oil lamps have been provided; these also serve for use as ordinary lamps for night work. They are of the same pattern as those used for ordinary army signalling purposes, but of the largest size.

Illumination of channels defended by submarine mines.

Several systems have been devised for illuminating channels at night, by means of the electric light, the Drummond light, magnesium light, &c., and there is no doubt that, where practicable, such devices should always be used. The action of the several lights named is too well known to render it necessary to describe them here, but there is one device which might be easily made use of in connection with a guard boat. A substance producing by its ignition a very bright light, (magnesium for example would

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should be taken off the fire for a moment, otherwise some of the fitments might be burst.

be one of the best), might be arranged on a float, and a guard boat carrying a few of these might, if chased, ignite and throw one out. The apparatus should be provided with a short fuze, to enable the guard boat to get a little distance off before the actual light burst out. In this way an enemy's vessel might be seen and fired on by the guns of a battery. Boxer's parachute shells, or any similar device, would also be useful for illuminating purposes.

Rockets containing magnesium lights.

Rockets, containing magnesium lights, arranged to be released by the explosion of a bursting charge, have been suggested for lighting up channels by Mr. Brock, of the Crystal Palace; a few of these were tried and proved themselves to be so efficient, that it would seem desirable that further experiments in this direction should be instituted. The light in each of these rockets was provided with a parachute, which prevented its falling too rapidly downwards. The great advantage of a rocket, over Boxer's parachute shell, for this purpose is, that it can be fired with ease from a boat, whereas Boxer's apparatus must be fired from a mortar. In watching a system of submarine mines, a guard boat provided with a few of these rockets would possess a great advantage, as they could be easily thrown up towards a supposed enemy, and a good view obtained of any vessel approaching the mines at night.

Experiments with Siemens' dynamo-electric light.

Experiments were tried at Sheerness in December, 1871, with a large Dynamo-electric light, manufactured by Messrs. Siemens, Brothers, of Charlton, for the special purpose of illuminating water channels. The apparatus itself weighed about 14cwt., and was worked by means of a 6-horse power agricultural steam-engine: with the exception of some mechanical defects, which do not appear to be very difficult to re-arrange, there seems to be no reason why this apparatus should not perform the work, for which it has been designed, in a satisfactory manner, as far as the mere machine itself is concerned. The weather was, on the whole, unfavorable, having been generally foggy: one night, however, was sufficiently clear to see the lights of Southend and Shoeburyness, at a distance of about seven miles, very distinctly. On this night, the rigging and masts of barges and vessels at anchor could be made out, by those stationed in the vicinity of the electric light, at a distance of from 1000 to 2000 yards only, but scarcely more distinctly than they could be seen with an ordinary night-glass, while a small steamer, (the Bustler), at a distance of 3000 yards, and a man-of-war's, 30ft. pinnace, at a distance of 2000 yards, were not discovered. From these experiments it would appear therefore that, used in this way, an electric light would not be of any great advantage. There is one mode, however, in which it is probable that it might be more effectively employed, namely, to direct it outwards, towards the system of mines or channel to be watched, and send boats some distance out

to look forward towards the enemy. In such a position, with the light behind them, they would probably be able to see a considerable distance beyond them, whereas they themselves would probably be invisible, in consequence of the well-known dazzling effect of a powerful light when the eye is directed towards it. If a boat took up a station at one of the junction boxes, provided with a line for telegraphic purposes, as suggested in page 192, all the enemy's movements could, if seen in this way, be signalled to Head Quarters with facility. Further experiments are required, to determine the extent to which a boat in such a position would be rendered invisible. This effect would depend on the distance of the electric light, and would probably be limited, very strictly, to the line in which that light is focussed.

CHAPTER X.

Electrical Igniting Agents.

Having carried our electric cables into the fort, the next point to be considered is the agent by which the mines shall be fired.

Ignition at will, or by circuit closer

Ignition may be effected, either at will or by a self-acting arrangement, the vessel, in the latter case, herself completing the circuit by means of a circuit closer. The means employed in firing at will may be a magneto current, frictional electricity, or battery power; when a circuit closer is used, battery power, directly applied, is most convenient. The Austrians employ battery power, combined with an intensity coil, in connection with their self-acting, circuit closing apparatus, and the Prussians use the induced currents, produced by a dynamo-electric machine, in connection with a self-acting circuit closer, in their system of outrigger torpedoes. These may, however, be considered exceptional cases, in no way affecting the general application of battery power under such circumstances.

Firing at will.

First, with reference to the employment of a magneto current. Several instruments for the production of a current of this nature have been devised, and perhaps the most beautiful and ingenious of them is that of the well-known electrician, Professor Sir Charles Wheatstone; a description of it, which is given in the printed *Course of Instruction in Military Engineering*, published by authority, page 152, will serve as a key to the construction of all instruments of this nature.

Wheatstone's magnetic exploder.

The mode in which the uneven succession of currents, produced by a magneto-induction apparatus, is overcome, and which is not given in the *Course of Instruction in Military Engineering*, is very ingenious. Sir Charles Wheatstone has placed two bobbins on each pole of the magnets instead of one, by which arrangement he obtains the result shown in *Plate* LX., *Fig.* 1, where, if n, n', s, s' be the bobbins, and a the armature revolving in front of them, the latter is so arranged, that at the moment when it is breaking contact with n' and s, it shall be making contact with n and s', and thus the difficulty occasioned by the uneven succession of currents, which would occur if only one pair of bobbins were used, is got over; for the coils are so

arranged that, for example, in the position of the armature shewn, the larger or breaking contact current, induced in the coils *n* and *s*,′ is transmitted in the same direction as the smaller or making contact current, induced in the coils *n*′ and *s*, and thus we obtain an even succession of currents, first in one direction, and then in the opposite; for as the armature continues to revolve, it first makes, and then breaks contact, with the opposite pairs of bobbins, simultaneously, and with great rapidity.

The defect of this instrument, is the small quantity of the electrical current induced, which renders it necessary to have very perfect insulation throughout the whole of the connections.

Arrangement of fuzes for Wheatstone's exploder.

Fuzes to be fired with this apparatus must be arranged in simple divided circuit, and the number of charges, which may be fired in any given group, depends on the extent of the leakage or loss of current through the ends of the conducting wires laid bare, after any given number of mines in such group have been fired. Though practically simultaneous, the charges are really fired in extremely rapid succession, and as each explodes a greater surface of bare wire is exposed, and brought in contact with the surrounding earth or water in which the mines are placed. When this bare wire amounts in the aggregate to a conducting surface, sufficient to carry away a large proportion of the current generated, no further fuzes will be exploded. The conducting power of water, especially salt water, is much greater than that of earth, and, consequently, though as many as 10 fuzes may be fired with this apparatus in dry earth, we cannot reckon on igniting more than four with certainty in salt water.

Beardslee's magneto-electrical exploding machine.

Mr. Beardslee, of New York, has designed an instrument of somewhat similar construction to Wheatstone's, capable of producing a greater quantity of electricity with less electro-motive force. The general principles of this instrument are similar to those of Wheatstone's.

It consists of a compound magnet, (said to be made of cast-iron), provided with ten arms, arranged like the spokes of a wheel, each arm being composed of four separate magnets about $\frac{1}{4}$-inch in thickness. It is mounted on a central axis, upon which it may be made to revolve, with very great rapidity, by means of wheel-gearing and a handle.

The armatures, with their coils of insulated wire, (about 24 gauge), are fixtures; they are arranged in two circles, and are placed in as close proximity to the arms of the magnet as is possible without touching them, one coil being above and the other below each arm. The coils are connected together, in four series of five each, by means of two insulated wires; each of these terminates in a separate metal plate, whereby each is brought into distinct connection with the external poles of the machine, (communicating with the conducting wires). By this arrangement, each set of poles of all the coils is connected with

one pole of the apparatus. The machine is enclosed in a box, in which it is very firmly fixed by means of a stout iron framework. On an inner lid of the box is the handle, by the movement of which the magneto-electric current is developed; the binding screws, which are immediately over the enclosed pole plates, receive the conducting and earth wires; and lastly, there is a key arrangement, by the movement of which, at the required moment, when the magnet is revolving at its maximum velocity, the electric current is passed to the binding screws, and thus to the charge which is to be exploded. An outer lid encloses the entire mechanism, so that all parts are protected from injury during transport. A detailed description of Beardslee's magneto-electrical machine, with illustrations, is given in the *Report of the Floating Obstruction Committee.* It was especially adapted for use with Beardslee's fuze.

Dynamo-electrical machines.

Kindred instruments to the above, called dynamo-electrical machines, are manufactured by Messrs. Siemens, Brothers, of Charlton, and Mr. Ladd, of Beak street, London. An important difference exists in these instruments, as compared with the ordinary magneto-induction apparatus, namely, that they are independent of permanent magnetism for the current induced.

Siemens' dynamo-electrical machines.

The instrument made by Messrs. Siemens, is very similar in its arrangements to any magneto-electrical apparatus of ordinary construction, but in it the permanent magnet is replaced by a piece of soft iron, *c*, *Plate* LX., *Fig.* 2, round which coils of fine insulated wire, *a*, *a*, are wound; *b* is a Siemens' armature of soft iron, on which a coil, in metallic connection, through a commutator, with the coil *a*, is wound. When this armature is made to revolve rapidly, the residual magnetism, in the horseshoe-formed piece of soft iron *c*, induces a series of currents of electricity in the coils of the armature; or if there is absolutely no residual magnetism in *c*, it is only necessary to touch it with a permanent magnet for a moment, when beginning to move the armature *b*. The currents thus induced in the coils of *b*, circulate through the coils *a*, *a*, and increase the magnetism, which in its turn reacts on the coil *b*, and induces a stronger series of currents. In this way the one may be made to react on the other, till *c* becomes a powerful electro-magnet, and a very considerable current is induced in the coils. This occurs after a very few turns of the handle; the armature, being connected therewith by multiplying gear, revolves very rapidly while the handle is turned. The current may be utilised in any combination of a similar nature to that for which the ordinary current, produced by a magneto-electrical machine, is available, by simply discharging it through any circuit required.

For work, the apparatus is fitted with a strong wooden case, from which, however, it may be withdrawn with facility for examination. Terminals are provided, on the outside of this

wooden case, for the attachment of the earth and line wires of the circuit to which the fuzes to be fired are connected: this having been done, it only remains to turn the handle rapidly round, by which means the current is induced and stored up in the coils, and finally, when brought to a maximum, discharged through the firing circuit, by a self-acting arrangement.

This property of soft iron was discovered by Dr. Werner Siemens, of Berlin. There is always sufficient residual magnetism in the soft iron to induce a small current in the coils, and in these instruments the reaction of magnetism on currents, and *vice versa*, increases this residual magnetism very rapidly.

Experiments with Siemens' dynamo-electrical machine.

One of Siemens' small instruments, weighing 28lbs., has been tried at the School of Military Engineering, at Chatham, with the following result:—

Twelve Abel's fuzes, out of twenty, placed in continuous circuit in dry air, were exploded at the second discharge. Twelve Abel's fuzes, placed in divided circuit in dry air, were fired, one at the first discharge, and eleven at the second. The instrument is arranged, so that several turns of the handle are made in the first instance on short circuit, in order to accumulate a sufficient charge in the coils, and, on arrival at a certain point, this accumulation is discharged through the main circuit, in which the fuzes to be fired are placed. In order to produce this latter result, the short circuit is broken, by means of a cam in connection with, and turned by, the handle by which the armature is put in motion, which allows a spring to descend, and simultaneously to break the short, and complete the firing, circuit. The reason of the partial failure in the two experiments mentioned was, that the handle had been turned very nearly up to the point where the action of the cam, throwing in the firing circuit, took place, and, consequently, instead of the accumulated charge produced by several turns, being stored up, only that due to one or two turns was discharged through the firing circuit. It is necessary, therefore, in using this instrument, to commence turning the handle from that point where the maximum number of turns, before the discharge, is obtained. In subsequent experiments, where this precaution was taken, no failure of the nature described took place. It may be assumed, therefore, that the instrument in question possesses the power to fire 12 Abel's fuzes, either in continuous or divided circuit, in dry air. As the fuzes are all fired by a single discharge, and not by a succession of short currents, as in Wheatstone's magnetic exploder, the number which may be relied on to be fired in earth, dry or damp, or in sea water, depends, to a considerable extent, upon the quality of the insulation of the electric cable. To test this, a single Abel's fuze was fired with this instrument through a quarter of a mile of cable, (a strand of 7 No. 22 copper wires, insulated with Hooper's di-electric to a diameter of $\frac{3}{16}''$). It failed to fire with a leak of $\frac{1}{16}''$. With the

PLATE LX.

ELECTRICAL MAGNETO & DYNAMO-INDUCTION FIRING APPARATUS.

Fig. 1.

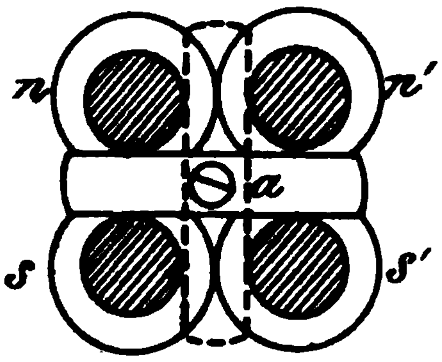


Fig. 2.

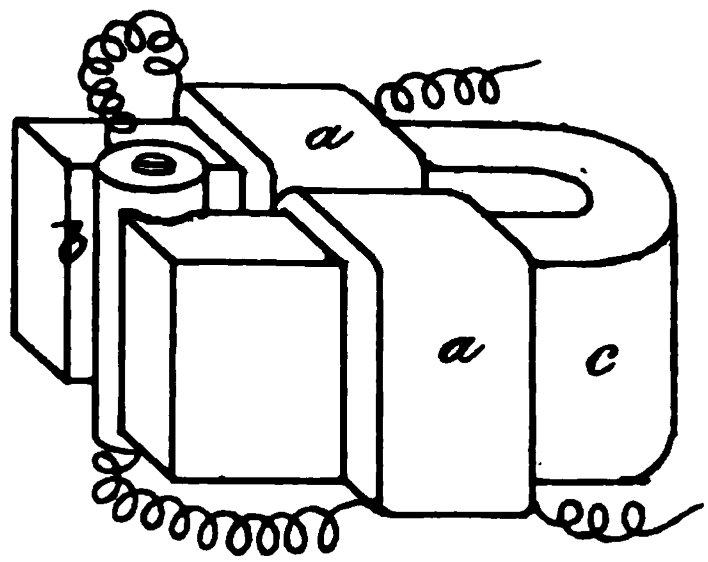


Fig. 3.

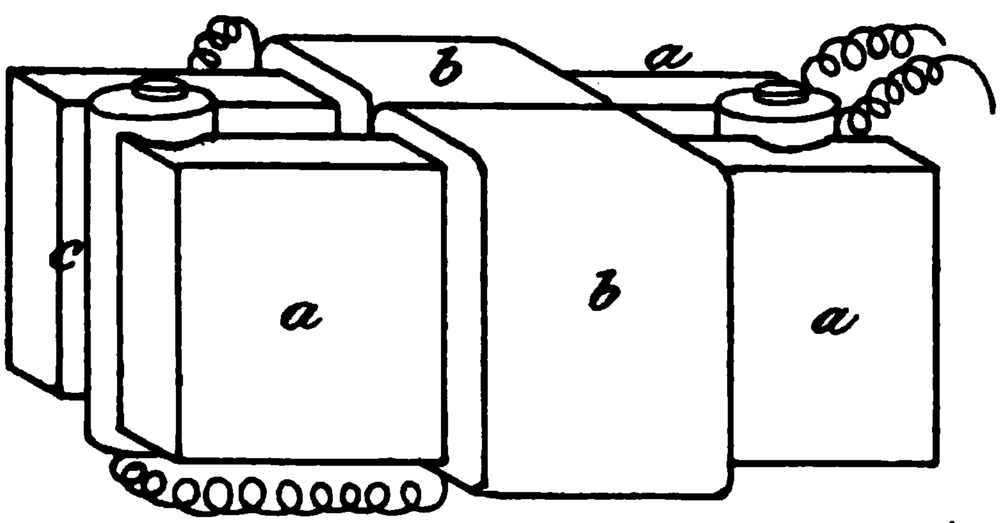
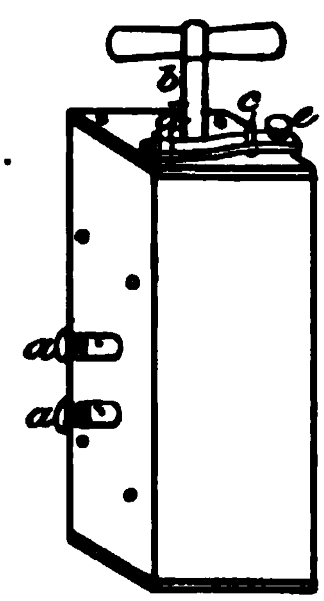


Fig. 4.



Lithographed at the S. M. E. Chatham. *B. Butler, Corpl. R. E.*

same cable, the ebonite frictional machine failed with a leak of $\frac{1}{8}''$. With a conductor consisting of $1\frac{1}{4}$ miles of similar cable, the dynamo-electric machine failed to fire the fuze with a leak of $\frac{1}{32}''$. With the same cable the frictional machine failed with a leak of $\frac{1}{4}''$. As regards power to overcome a leak, therefore, a dynamo-electrical machine of this weight, (28lbs.), is about on a par with a Wheatstone's exploder, weighing 31lbs., which, as well as the frictional machine, has been tried against it for the sake of comparison.

Machines of this nature may be made of considerable size, and, where portability is not essential, may be arranged to develop a very considerable electrical current.

Dynamo-electrical machine used by the Prussians.

Siemens' dynamo-electrical machine is used in the Prussian service, in connection with their system of submarine mines, as well as in their torpedo boats for firing outrigger torpedoes. In this latter arrangement, the handle of the apparatus is continuously turned on approaching a vessel to be attacked, and when the torpedo strikes the vessel's side, the circuit is closed, by means of a circuit closer adapted for the purpose, and the charge is fired.

Dynamo-electrical machine adopted for British service.

A dynamo-electrical machine, of Siemens' form, of somewhat larger size than that with which the experiments above enumerated were made, has been adopted for submarine mining service in this country. It is similar to that approved for the siege train equipment provided for Engineer service, and weighs 44lbs.

Ladd's Dynamo-electrical machine.

Mr. Ladd, of Beak Street, London, has invented another instrument adapted to the explosion of mines, the principle of which is very similar to that of Siemens' dynamo-electrical machine; the arrangements, however, slightly differ, inasmuch as Ladd employs two armatures, one to create the electro-magnet, and the other to produce a current therefrom, with which to perform any work required. *Plate* LX., *Fig.* 3, gives the general arrangements of the instrument; *a*, *a* are two soft iron bars, round which coils of fine insulated wire *b*, *b* are wound, in metallic connection, through a commutator, with the coil of an armature *c* revolving between their extremities. When the armature *c* is made to revolve, exactly the same effect is produced as in Siemens' instrument, and the result is that the two bars *a*, *a* become very powerful electro-magnets, the poles of which are so arranged as to be opposed to each other at their extremities. Now instead of discharging the current thus induced through his working circuit, to fire fuzes, or perform any other work, which necessitates the beginning again, as it were, to create a new current, Mr. Ladd introduces a second armature *d*, revolving between the soft iron bars, from which he obtains his working current; the magnetism of the bars is thus always kept up. The residual magnetism of the system is always sufficient to commence the action described, except, possibly, when an

instrument had just been made, and had never been used, when it might be necessary to touch the bars with a permanent magnet, or pass a voltaic current through the coils for an instant, to obtain the magnetism required. An instrument of this nature was exhibited at the Paris Exhibition of 1867; it was only 24in. long, 12in. broad, and 7in. thick, but the effects produced by it, when worked by a steam-engine of 1-horse power, were very great, and would seem to augur well for the future of this system, which Mr. Ladd proposes to apply to the production of an electric light for lighthouse purposes. The principle is, of course, equally applicable to the ignition of charges of gunpowder, or other explosives.

The following description of another instrument of a similar nature, is extracted from the *Report of the Floating Obstruction Committee*, page 86:—

Magneto "exploder" by Markus, of Vienna.

"A small magneto-electric exploding machine, which was first devised by Herr Markus, an Austrian philosophical instrument maker, at the suggestion of Baron Von Ebner, (after the latter had witnessed the performances of Wheatstone's instruments and Abel's fuzes in England in 1862), and which is stated to be employed in the Prussian service, was obtained by government for the purposes of the committee from Messrs. Gessler and Co., of Berlin. This instrument is not more than half the size of Wheatstone's exploders, from which it differs materially as regards the mode by which the generation of magneto-electric currents is effected. It was only disposed of to the English government upon the understanding that it was not to be examined, and no detailed description of its construction can, therefore, be attempted, but the mode of using it affords a sufficient indication of the manner in which the magneto-electric current is generated. The magneto-electric apparatus is completely enclosed in a square oblong metal case, to one side of which are fixed two binding screws *a*, *a*, *Plate* LX., *Fig.* 4, for connecting the instrument with the conducting wires, while one of the ends, forming the top of the case, carries the arrangement for 'setting' the instrument and firing the mine."

Mode of using the instrument.

"Before this magnetic exploder is connected with the conducting wires, a key, with powerful leverage, *b*, fixed upon the top of the instrument, to which it also serves as a handle, is turned to the right as far as possible. By this operation the armature of the enclosed magneto-electric machine is separated from the magnet, and placed under the influence of a powerful spring. This spring is in connection with a pin, *c*, which projects from the top of the instrument, and moves, as the key is turned, in a slot of a long spring, *d*, one end of which is fixed upon the instrument, while the other carries a knob made of ebonite, *e*. When the key has been turned to the full extent, the

pin, which controls the armature spring, has become firmly fixed by its head in the slot of the external spring, *d*, and the instrument is now ready for action at any moment. It is then connected with both conducting wires, and the explosion of the charge is accomplished by pressing down the ebonite knob, *e*, whereupon the armature spring is released by the liberation of the pin, *c*, from the outer spring, *d*, and the armature returns to the magnet with great velocity, an electric current being thereby established."

"This instrument is even more portable than Wheatstone's ordinary exploder, and is fully as powerful—*i.e.*, it is capable of exploding as many, if not more, charges in simple circuit; but it is much more limited in its power of firing charges through a divided circuit, because it is incapable of furnishing a succession of currents, such as those obtained by means of Wheatstone's and Beardslee's instruments."

"Several of these instruments, of different size and power, constructed by Markus, were exhibited among the collection of military implements sent to the recent Paris Exhibition by the Austrian government. The smallest of the machines was stated to be capable of exploding five or six of Von Ebner's fuzes, and the largest fifteen, in simple circuit. That officer states, that the magneto-electric instruments of Markus have been introduced into the Austrian service for land operations, in place of the frictional electrical machine."

"Some very efficient rotatory magnetic exploders, similar in their powers to Wheatstone's ordinary exploders, and differing only from them in details of construction, were also shown in the Exhibition of the Austrian War Department at Paris."

Fuzes, adapted to electricity of high tension, may also be fired by means of the induction coil, for which they must be connected in simple divided circuit, for the same reason that it is necessary so to arrange them for Wheatstone's magnetic exploder, viz., that the action produced is a very rapid succession of currents of very short duration. *Induction coil.*

The defects of all these instruments for submarine mining purposes, are the same as those of Wheatstone's magnetic exploder, viz., the small quantity of the current, which renders it necessary to employ a cable with very perfect insulation.

Next, as regards the use of frictional electricity, as an exploding agent for submarine mines. The well-known Austrian frictional machine, designed by Baron Von Ebner, General of the Austrian Corps of Engineers, is a very good type of instruments of this class. Several instruments of this kind, but slightly differing in size and construction, were exhibited at Paris in 1867 by the Austrian War Department. Some of them were made with glass discs, and enclosed in a wooden box, but the best for military purposes are those in which the glass discs *Frictional electrical machines.*

are replaced by ebonite, as described in *The Course of Instruction in Military Engineering*, page 156, par. 334.

These instruments produce a charge of electricity, much larger in quantity and higher in tension than either the magneto-induction or dynamo-electrical machines. One of their defects is the time required to charge the condenser, which takes from 20 to 30 seconds, and the condenser must be recharged after each explosion. There is also a certain liability for the charge to leak out of the condenser when the air is highly charged with moisture, but when the instrument is in good working order an Abel's fuze, (No. 1 fuze, electrical, Abel), may be fired with it, from 15 to 20 minutes after the condenser has been charged, and under favorable circumstances we have fired one after an interval of 6 hours.

The chief defect of this instrument is the danger, when using it in connection with Abel's ordinary mining fuze, (No. 1 fuze, electrical, Abel), of accidental ignition to mines, the conducting cables of which may be in the vicinity of that in connection with the mine to be fired, as shown by the experiments detailed in page 121. Some further experiments have since been made at the School of Military Engineering, Chatham, to ascertain the limits, within which the inductive action is so energetic as to render it dangerous to lay electric cables, when mines are to be fired by means of frictional and induced electricity. From these it is evident that the utmost care is necessary in using the frictional machine.

On the 18th of May, 1870, two half miles of electric cable, each consisting of a strand of 7 No. 22 copper wires, insulated to a diameter $\frac{3}{10}''$ with Hooper's patent di-electric, were laid out and connected with fuzes. The fuzes were placed 20 yards apart, and the line was, in each case, put to earth beyond them. One of the cables was connected with the instrument used for firing the fuze, the end of the other, at the point from whence the fuzes were fired, being carefully insulated. The two cables were laid parallel to each other as far as they would go, till it became necessary to diverge to the positions where the fuzes were to be placed; they therefore lay under conditions favorable for inductive action for nearly half a mile. The annexed table, page 207, gives the results obtained:—

Frictional electricity only applicable to exceptional cases.

From this it is evident. that the use of frictional electricity, in connection with a system of submarine mines, is limited to very exceptional cases. For certain purposes, as, for example, with isolated mines, this instrument is, no doubt, a valuable agent, but in consequence of the great danger, inseparable from the inductive effect of the discharge, to which it is subject, it should only be entrusted to careful men, who are thoroughly acquainted with its use.

Frictional

Experiments made in Austria have proved that, when a return

TABLE OF EXPERIMENTS, TO ASCERTAIN THE LIMITS WITHIN WHICH THE INDUCTIVE ACTION OF FRICTIONAL ELECTRICITY IS SUFFICIENT TO FIRE AN ABEL'S FUZE, UNDER THE CONDITIONS SPECIFIED.

Distance of cables apart.	Instrument used	No. of turns given to Frictional Machine.	Results.
6 feet.	Frictional.	20	Both fuzes fired, one directly, one by induction.
8 „	„	4	„ „ „
8 „	„	4	One „ on direct circuit, second fuze not fired by induction.
9 „	„	20	Both „ one directly, one by induction.
12 „	„	20	Both „ „ „
15 „	„	10	One „ on direct circuit, second fuze not fired by induction.
15 „	„	20	One „ „ „
15 „	„	30	Both „ one directly, one by induction.
20 „	„	20	One „ on direct circuit, second fuze not fired by induction.
20 „	„	30	Both „ one directly, one by induction.
30 „	„	30	Both „ „ „
40 „	„	30	One „ on direct circuit, second fuze not fired by induction.
40 „	„	40	One „ „ „
40 „	„	50	One „ „ „
40 „	„	50	*One „ „ „
35 „	„	50	One „ „ „
30 „	„	50	Both „ one on direct circuit, one by induction.
Touching	Dynamo-electric Machine.		One „ on direct circuit, second fuze not fired by induction.
„	„		One „ „ „
„	Wheatstone's Magnetic exploder		One „ „ „
„	„		One „ „ „

* The second fuze was changed in this case, in order to ascertain that the failure to fire did not arise from a defective fuze, or one comparatively less sensitive.

machine used by the Austrians.

wire is used, frictional electricity may be employed to fire high tension fuzes without any danger of igniting, by induction, those attached to conductors, lying in the vicinity of that through which the current may be discharged. The Austrians have consequently adopted an ebonite frictional machine, very similar in general construction to that originally designed by Baron Von Ebner, for their submarine mining service, and have turned their attention to the improvement of the instrument. In order to reduce, as far as possible, that effect of loss of charge by leakage after the condenser has been charged, they have enclosed the whole apparatus in an air-tight cover, through which the terminals, for attachment to the insulated conductors, in connection with the fuzes to be fired, alone project. It is also understood that they have adopted cat skin rubbers, thus obviating the necessity of using amalgam, which was required with the apparatus as originally designed:—and they have arranged the whole in an extremely compact and portable form.

The dynamo electric machine seems to be the best for general use.

Taking into consideration the advantages and defects of each of the instruments described, it would seem that the dynamo-electrical machine is the best adapted for general use in connection with a system of submarine mines. When made of moderate size it is sufficiently portable for all practical purposes, while at the same time its power to generate a charge of electricity renders it available, under nearly all conditions, for the ignition of a mine with certainty. The absence of permanent magnets gives it an advantage over Wheatstone's magnetic exploder and Markus' machine, and there is, with the smaller form of instrument, no danger of explosion by induction, as in the case of the frictional machine. It has accordingly been adopted for submarine mining service. When the frictional machine is employed, the utmost care must be used, and where there are several mines they must be connected by return wires, and earth plates must not be introduced into the system.

Ignition by battery power.

We now come to the ignition of submarine mines by battery power; for use in connection with forts, or in stationary positions, there is no doubt that the battery is by far the most important agent.

Battery for use with platinum fuse.

Where a platinum wire fuze is used, a current of large quantity is necessary to ensure ignition. For this purpose Grove's or Walker's, or some battery producing electricity of the requisite nature, must be used. This question has already been discussed, see page 96 and those following.

Grove's battery.

A description of Grove's battery, with the general principles to be borne in mind in using it, is given at page 138, par. 295, of *The Course of Instruction in Military Engineering*, and the paragraphs following.

Walker's zinc-carbon

A platinum wire fuze may be used in connection with Walker's zinc-carbon battery. Some experiments have been tried

at the School of Military Engineering, at Chatham, with this form of battery. *battery.*

Each cell was composed of two cylinders of zinc, each $\frac{3}{16}''$ thick, 7" long, and 3" in diameter, connected together so as to form a single metallic plate, and two cylinders of graphite, each $\frac{3}{8}''$ thick, 7" long, and 3" in diameter, similarly connected. The cells were formed of gutta percha pots, $7\frac{1}{2}''$ in diameter, and 7" deep, capable of containing about half a gallon of liquid. If the battery plates had been made in one single piece, instead of in two portions, the whole would have been very much more compact, but at the time it was made the manufacturers had no larger plates in stock, and those described above were used to save time. *Experiments*

The battery was made up on the 10th of December, 1869. The number of cells employed was four, and $\frac{3}{10}''$ of platinum wire, weighing 1·6 grains to the yard, was employed as the standard of measure to ascertain the fusing power of the current. The electrical resistance of one turn of the Rheostat employed was ·0249 B.A. units. The proportion of acid to water used in the cells, was one of acid to ten of water.

When first made up, the platinum wire ($\frac{3}{10}$in.) was fused through 21 turns on the Rheostat. After having been a few days mounted, the fusing power of the battery increased, and it attained its maximum on the 20th December, 10 days after having first been mounted, when the platinum wire was fused through 31 turns on the Rheostat. It remained very constant for a month from that date, and on the 19th of January it fused the platinum wire through 30 turns of the Rheostat. From that time it gradually decreased in fusing power, and on the 25th of February it fused the platinum wire through 18 turns only of the Rheostat. It was freshly made up on the 26th of February, and five minutes after being remounted fused the platinum wire through 32 turns of the Rheostat: this improvement, as compared with the results when the battery was originally made up, on the 10th of December, may be accounted for by the fact that, probably before this second making up, any impurities in the zincs had been decomposed by the action of the acid, and a more uniform surface had resulted. From the 26th of February, the battery worked with great regularity, up to the 22nd of March, fusing the platinum wire through not less than 30 turns on the Rheostat, and, on two occasions, the 5th and 7th of March, fusing it through 35 turns satisfactorily.

The results obtained proved this battery to be very constant, so that there need be no further doubt on that account as to the use of the platinum wire fuze. It was observed that on the 12th of February, when the battery was moved from one table to another in the same room, there was a slight depreciation in the fusing power of the current, but that it subsequently, to a *Battery proved very constant.*

certain extent, recovered itself. It should, therefore, be moved as little as possible, but as it is only applicable to permanent stations this is not of much consequence. It was noticed too, that if the circuit was kept closed—that is to say, a constant flow of current kept up—its working power was materially diminished, as shown by the smaller number of turns through which the platinum wire was fused. As, however, in any system of submarine mines, the circuit would only be closed for an instant, as each mine was fired, and as no continuous work would be required, this latter, though a fact to be noted, need not interfere with its use for such a purpose. Subsequent experiments have proved it to be a very good battery for firing purposes; a form of it, in which the plates are of the ordinary trade size, and consequently easily procurable, has been adopted by the Torpedo Committee for this purpose.

Battery for use with tension fuze. To fire a fuze adapted to electricity of high tension, any of the ordinary forms of battery used for working a line of electric telegraph may be employed; the object in such a case being to obtain electro-motive force rather than quantity. It is of importance that the battery should be constant, that is to say, that it should be capable of being allowed to remain mounted, and ready for use, for a considerable time, say a month, and not, like Grove's, require to be taken to pieces and re-fitted every 12 hours; that it should generate a sufficient quantity of electricity to allow of a certain amount of leak or fault in a cable, and yet fire the fuze beyond that leak; and at the same time, that the electromotive force to be obtained from the battery may be such as, with a sufficient number of cells, to fire a service fuze with certainty.

When the approved form of service battery is not obtainable, a constant telegraph battery may be used. The best forms for this purpose seem to be Wollaston's sand battery, the Marié-Davy, Daniell's, and the Leclanché batteries.

Wollaston's sand battery. The ordinary form of sand battery is shown in *Plate* LXI., *Fig.* 1, twelve cells being united in a trough made of gutta percha. The usual dimensions of the plates are $3\frac{1}{2}'' \times 4\frac{1}{2}''$. They are alternately copper and zinc, connected together in pairs, by copper strips rivetted and soldered to them. The zinc plates are amalgamated with mercury, and the cells are filled with fine silicious sand, moistened with sulphuric acid diluted with water in the proportion of $\frac{1}{15}$. This battery developes a powerful current of electricity when first made up, but, when the circuit is kept constantly closed, it is very inconstant, and after being in use for a certain time, varying according to circumstances, it loses its power from several causes; the sand must then be washed out, and the battery made up again with fresh solution and the zincs re-amalgamated.

Defects. The great defect of the simple combination of zinc and copper

in dilute acid is, that the bubbles of hydrogen gas, resulting from the decomposition of the water by the electric current, adhere to the copper plate; they are in a state of electrical polarization, and being, moreover, in what is termed the nascent state, the hydrogen combines very readily with the oxygen of the sulphate of zinc, produced by the action of the battery, and metallic zinc is thus deposited upon the copper plates, and so, similar metals being opposed to each other, the action of the battery ceases. Many methods have been adopted to get rid of the hydrogen. In Grove's and Daniell's batteries, it combines with the oxygen of the solution in which the electro-negative metal is immersed. In Smee's and its kindred forms of battery, the hydrogen is assisted in escaping from the electro-negative plate by giving it a rough surface, presenting a multitude of small points from which the bubbles separate easily.

The sand is chiefly useful to prevent the acid from spilling when the battery is moved about, it tends also to make the action of the battery more regular; but it should not contain carbonates, such as carbonate of lime, or a chemical action takes place with the sulphuric acid, which is detrimental to the battery,

Improvements.

In the best form of this battery, a small gutta percha pipe is inserted in each cell, extending down to the bottom; through this, fresh diluted acid is poured in, from time to time, to make up for waste by evaporation. By thus introducing the fresh acid at the bottom of the cell, where the heavy sulphate of zinc gravitates, a more regular action is obtained. If the sulphate of zinc be allowed to accumulate in the lower part of the cell, a cross voltaic current is established, between the upper and lower portions of the plates, which are in solutions of different strengths. The effective current in circulation is thus diminished, and the upper portions of the zinc plates are rapidly dissolved away.

	lbs.	oz.
The weight of the 12 cell battery is—without sand or liquid	14	14
With sand	22	0
Sand and liquid	23	$12\frac{1}{2}$

It requires about 1lb. of mercury and two pints of acid per annum for each 12 cells.

For submarine mining purposes, the conditions are different from those which occur in the simple working of a line of electric telegraph, in which latter the circuit would be closed much more frequently and for longer periods. Under these latter circumstances its defects become much more apparent, as the mischief is done almost entirely when the circuit is closed. This fact, however, renders it less objectionable as a firing agent for submarine mines than as a battery for telegraphic purposes.

A solution of sulphate of zinc is sometimes used, as an exciting fluid, instead of diluted sulphuric acid, the effect under such

circumstances is, to a certain extent, to reduce the consumption of zinc with the reduction, however, of the active force of the current generated. A battery of this form charged with diluted sulphuric acid, is more energetic when first made up, while one charged with sulphate of zinc is, after coming fairly into a working state, more constant and requires less attention to keep it in good order. One advantage of sulphate of zinc is that, being in the form of crystals, it can be more easily stored and carried about than sulphuric acid; this is a very decided advantage on board ship.

This battery possesses another advantage for use on board ship, inasmuch as the liquid, being kept absorbed in the sand, is not liable to be spilt.

Marié-Davy battery.

There are several forms of the Marié-Davy battery which might be used for firing tension fuzes; this battery may be described generally, as consisting of plates of zinc and carbon, in a saturated solution of proto-sulphate of mercury.

One form of this battery, called "Silver's Marine Battery," has been manufactured by the Indian-rubber, Gutta percha, and Telegraph Works Company, of North Woolwich, expressly for use with Gisborne's system for signalling on board ship; it consists of a combination of zinc and platinized graphite plates, in a saturated solution of proto-sulphate of mercury. This is, perhaps, the best and most constant form of battery of this nature, but it is rather bulky. It could be used on board ship, having been expressly manufactured for sea service, to stand rolling about. The smaller forms of the Marié-Davy battery, which have been tried in the Electrical School at Chatham, though excellent when first made up, both as regards quantity and electromotive force, deteriorate very rapidly, and are not so good for submarine mining purposes as Daniell's and some other forms.

Daniell's constant battery.

Daniell's constant battery is well known to all persons engaged in working the electric telegraph, and consists of zinc and copper elements, the latter in a saturated solution of sulphate of copper. The copper plate is placed in a porous cell, with a quantity of sulphate of copper in the form of crystals, and water is poured in, which dissolves the latter, and the resulting chemical effect on the zinc sets up an electrical action: the outer cells, in which the zinc plates are placed, are simply filled with water. An excess of sulphate of copper must be placed in the porous cell, to keep the solution saturated, as it is termed, or in other words carrying a maximum of the sulphate of copper in solution.

Muirhead's form of Daniell's battery.

Muirhead's form of Daniell's battery would be a very good one for stationary submarine service. It consists of the usual Daniell's elements, zinc and copper plates, the copper in a porous cell, in a saturated solution of sulphate of copper, the outer cell

being filled, as usual, with water. The plates in this form of battery are comparatively large, which is advantageous when a defect exists in an electric cable. The greater the immersed surface of the plates, the greater the quantity of the current generated, when the external resistance is low.

Varley's form of Daniell's battery. Another form of Daniell's battery suitable for use with a high tension fuze, is Varley's. The arrangement of this battery is shewn in section in *Plate* LXI., *Fig.* 2; *a* is the outer cell, of cylindrical form and made of common glazed earthenware; *b* is the zinc element, a semi-cylinder, of thick cast zinc, occupying the upper half of the outer cell, and with a metal strip to connect it with the copper plate of the adjoining cell; *c* is the copper element, occupying the lower half of the cell, and consisting of a thin plate of copper wound round and round, so as to expose a sufficient metallic surface; the connection with the zinc plate of the adjoining cell consists of a copper strip, passing up through a glazed earthenware cylinder, *d*; *e*, is a porous diaphragm, consisting of several thicknesses of flannel, fitting tightly round the glazed cylinder *d*, and completely filling up the space between it and the outer cell, *a*. This flannel diaphragm is the chief peculiarity of this form of battery; it supplies the place of the porous cell in the other combinations of Daniell, and is so arranged that, taking advantage of the greater specific gravity of a solution of sulphate of copper over a solution of sulphate of zinc, each metal may be to a great extent in a solution of its own sulphate—that is to say, the copper in a solution of sulphate of copper, the zinc in a solution of sulphate of zinc. To set the battery in action, crystals of sulphate of copper are dropped, through the glazed cylinder *d*, into the lower portion of the cell, and water is then poured in. When first put together this battery does not at once produce a maximum of working current; it gradually improves for the first 48 hours, after which time it remains very constant for a long period. The flannel diaphragm produces a high internal resistance in the cell, until it becomes thoroughly saturated, when the resistance falls to that of the ordinary form of Daniell; taking it on the whole, it seems to be one of the most efficient batteries for submarine mining purposes, for which service its constancy,* when once fairly in action, is a very desirable quality.

Austrian battery for submarine mines. A battery, in connection with the submarine mines, exhibited by the Austrian Government at Paris, in 1867, is also worthy of notice. It was designed by Baron Von Ebner, General of the Austrian Imperial Corps of Engineers, and is described as follows, in the notices of objects exhibited by the Austrian War Department :—

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* It is, however, not superior in constancy to Muirhead's form of Daniell's battery, which has the advantage of Varley's in this respect.

"These batteries may be considered a modification of that known as Smee's.

"The large quantity of liquid contained in the cell retards considerably the tendency to alter its electro-motive force; platinized lead is used instead of platinized silver for the positive pole of the battery; and zinc, cut up into pieces, and held in a bath of mercury,—the whole in a porcelain cup, pierced so as to admit the diluted acid freely,—forms the negative pole of the battery.

"The consumption of zinc and mercury, which is very considerable in the ordinary battery, is in this materially diminished.

"These batteries have been employed for some time in working a system of telegraph instruments of dial form. In this case the force of the electric current required is very small, but so little zinc was consumed, that the batteries worked for 18 months without being touched."

The general form of one of these cells is shewn in *Plate* LXI., *Fig.* 3. It consists of a vessel of glass, *a*, about 12 inches deep, and $5\frac{1}{2}$ inches in diameter, to contain the diluted sulphuric acid, within which is suspended a plate, *b*, of platinized lead, which is bent round into a cylindrical form, to fit close round the inner surface of the glass. In the centre of this latter is hung the porcelain perforated cup, containing the cut-up zinc and mercury, to keep it, (the zinc), amalgamated. This is shewn in elevation at *c*, and in section at *d*.

The top of each cell is furnished with a porcelain cover, through which the wires, attached to the positive and negative plates, pass for convenience of connection. The cells are arranged in a wooden frame, in batteries of 12 each.

This battery is said to be very constant, but its great bulk is somewhat against it. It is understood that its details have been considerably modified and improved, since it was exhibited in Paris in 1867.

Leclanché battery.

In the French section of the Paris exhibition of 1867, a form of battery, invented by M. Leclanché, and manufactured by Messrs. Bonner, Jamin, Bailly, and Co., Paris, was shewn. *Plate* LXI., *Fig.* 4, represents a cell of this battery. The positive pole *a* consists of a plate of graphite in a porous jar, surrounded by a mixture of peroxide of manganese, and graphite broken up into small pieces. The negative pole *b* is a plate or pencil of amalgamated zinc. The whole is in an outer glass cell *c*, containing a solution of sal ammoniac. The peroxide of manganese is only a moderately good conductor of electricity. Powdered graphite is added, to improve the conductivity of the peroxide of manganese. This system may be described as a battery with one liquid, and of which the positive pole has a great affinity for hydrogen.

ELECTRICAL FIRING BATTERIES.

Fig. 1.

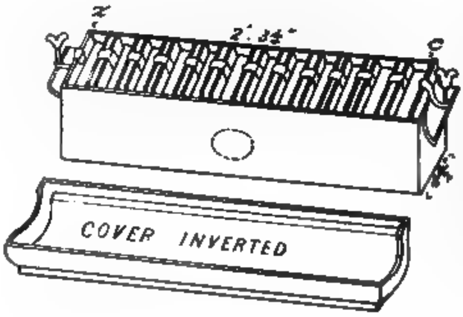


Fig. 2.

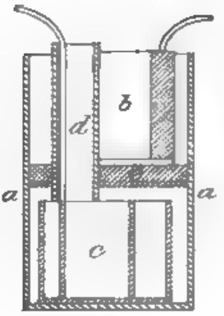


Fig. 3.

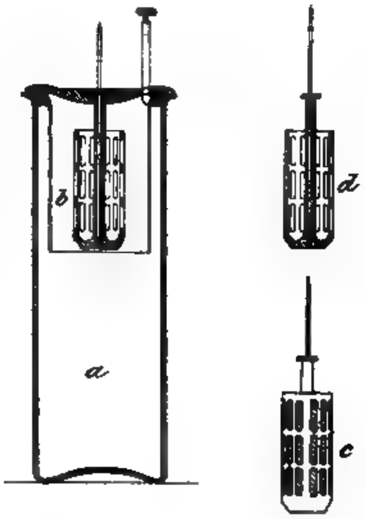
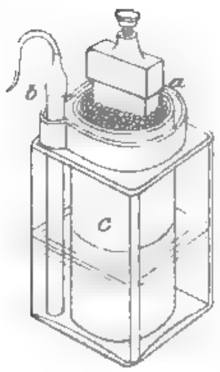


Fig. 4.



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The endosmosis, inevitable in a battery of two acids, is avoided in this combination. Zinc may be preserved for a very long period in a solution of sal-ammoniac, and peroxide of manganese being quite insoluble in that liquid, local chemical action is avoided. When the circuit of the battery is closed the hydrochlorate of ammonia is decomposed, and chloride of zinc is formed. The electro-motive force of this battery is very considerable, 28 elements of the Leclanché battery being said, by the makers, to be equal to 40 of Daniell's. Its internal, or liquid, resistance is also very small.

It has been adopted by the Chemins-de-fer de l'Est, de l'Ouest, du Nord, de Paris, and de Lyons à la Mediterrané, and in the first is said to have been tried for ten months* with very excellent results.

The advantages claimed for it are—Absence of chemical action when the battery circuit is not complete, and consequently no waste of material; it requires little or no looking after; the cost of maintenance is small; it cannot be injured by mixing or upsetting the liquids; the battery, ready for action, may be placed in store without deterioration or loss in its component parts; and it possesses great facility for transport, without injury to its working powers.

Batteries approved for service.

The Torpedo Committee has approved of batteries of the following construction for service:—

The several purposes for which voltaic batteries have been provided, in connection with the system of submarine mining operations are as follows: for firing the mines, for testing the fuze and electric circuits generally, for working the shutter apparatus, and for working the instruments used for telegraphic communication.

Firing battery.

For firing purposes, it is indispensible that the battery should be capable of firing either the platinum wire or tension fuze, so that it might be available either for a system of mines in connection with circuit closers, as shewn in *Plates* XVI. & XVII., or for electro-contact mines arranged on branches, as shewn in *Plate* XVIII.; that it should be constant, that it should be capable of doing its work in spite of a considerable fault of insulation, that it should be simple in its construction and easily managed, that the cells and plates should be of a convenient size, and such as could be readily procured in the market, that it could be easily packed for transport, and that it should not require strong acids. With a view to fulfil the above conditions, many experiments, on a small scale, were made which resulted in the recommendation, by the Torpedo Committee, of a modification of the Walker battery for the service required. Each element of this battery consists

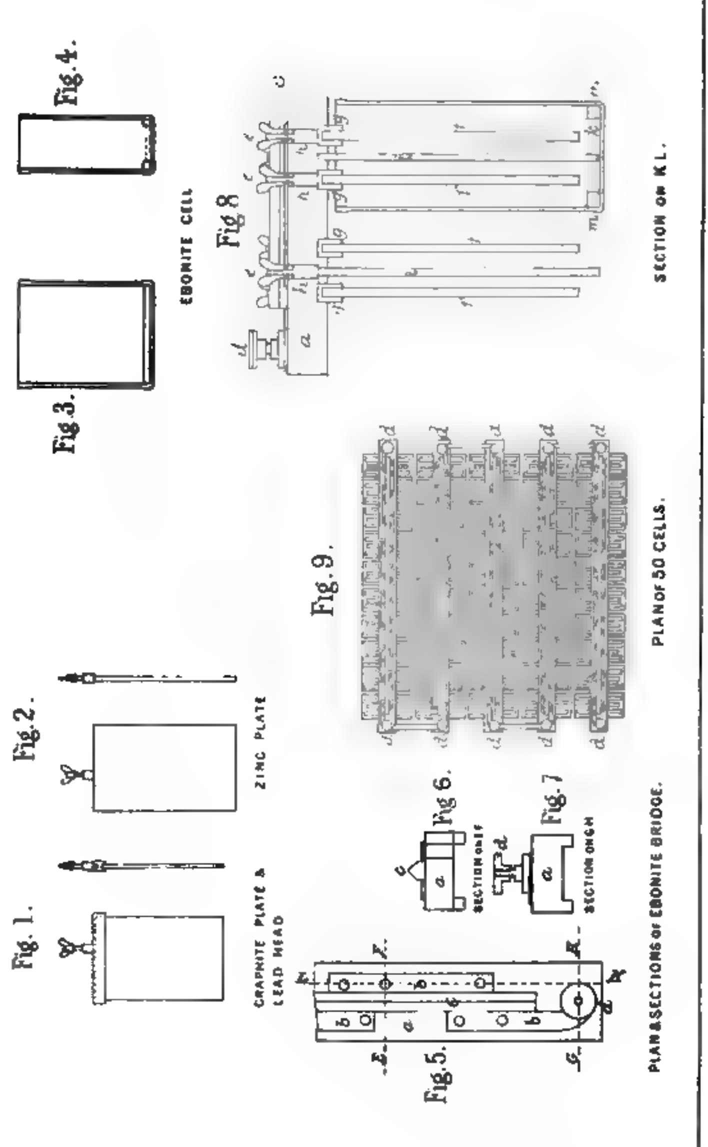
* This refers to the period of the Paris Exhibition in 1867. Subsequent experience has confirmed this conclusion.

of one zinc and two carbon plates, the whole contained in an ebonite cell of $1\frac{1}{2}$ pints capacity. The zinc plates are $7\frac{1}{2}$in. long and 4in. broad, and the carbons 7in. long, including the head, and 4in. broad: the head of the carbon plate is formed of lead cast on, a number of holes having been first bored in the carbon plate, through which the lead runs and forms a firm connection with the carbon. The battery has one liquid only, namely, dilute sulphuric acid, in the proportion of 1, by volume, of commercial sulphuric acid to 10 of water. The zinc plates are well amalgamated with mercury, the carbon plates are platinized, a recess is provided in the bottom of each cell to contain mercury, so that the lower end of the zinc plate, when immersed in the liquid, may dip into the mercury. The carbon plates are cut somewhat shorter so as not to touch the mercury, which would put the battery on short circuit. An ebonite bridge is provided, of sufficient strength and length to connect together and support 10 cells of the battery: it is 31in. long, 2in. broad, and 1in. deep. The battery is so constructed that the plates, connecting pieces and terminals, ebonite bridge and cells, can all be packed separately for transport, and the whole readily put together when required for use. The electro-motive force of one cell of the battery, compared with a standard cell of Grove's, is as $6\frac{3}{4}$ to $10\frac{1}{3}$. Its internal resistance is about $\frac{8}{100}$ of a unit, that of Grove being $\frac{8}{100}$ nearly. The work done by Grove's cell through any circuit is very much greater than that done by a cell of Walker's form of battery. To provide a margin for a fault in the electric cable, and increased electrical resistance in the circuit, or any other unfavourable conditions, the cells have been constructed of such a size, that two cells coupled in series will fuse two platinum wires of the standard gauge and lengths, ($\frac{3}{10}$in.), placed side by side. For fuzing a platinum wire with additional resistance interposed, two additional cells will be required for every ohm of resistance, the earths and return circuit through salt water offering no appreciable resistance. Thus if x be the number of cells required and R the resistance of the circuit in ohms

$$x = 2.R + 2.$$

This equation is true for a momentary effort of the battery when the metal plates have been recently lowered into the cells: should they, however, continue immersed in the liquid for a period of 48 hours, the battery may lose about $\frac{1}{3}$ of its electro-motive force. For ordinary work, it is considered sufficient to provide twice the calculated amount of battery power and one half of the working number of cells in reserve. For the reason above-mentioned, the battery is fitted with a lifting arrangement, for raising the cells out of the liquid and lowering them readily when the battery is required for use. With the exception of an occasional addition of a little dilute sulphuric acid to the different cells, as

FIRING BATTERY.



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the liquid evaporates, the firing battery may be kept always ready for use and requires no further attention for months. A daily record of the strength or heating power of the battery should be kept: this is done by noting the number of units of electrical resistance, through which the standard wire is fused. This serves to direct attention to any defects that may occur in the battery circuit, such as the oxydation or accidental disconnection of any of the binding screws.

Details of firing battery.

The details of the firing battery are given in *Plate* LXII. *Fig.* 1 shows a front and side elevation of the graphite plate, with its lead head and binding screws complete; *Fig.* 2 shows similar elevations for the zinc plate; *Fig.* 3 shows a longitudinal, and *Fig.* 4 a transverse section, of one of the ebonite cells; *Fig.* 5 shows a plan of the ebonite bridge; *Fig.* 6 shows a transverse section through this, on the line E F; *Fig.* 7, a transverse section through it, on the line G H; and *Fig.* 8, a longitudinal section through it, on the line K L. In the latter figures, *a* is the ebonite bridge; *b b* the brass strips, forming the connection between the proper metal plates in adjacent cells; *c* is an ebonite rib, running down the centre of the ebonite bridge; *d* is a terminal, through which the battery is connected to the firing circuit or to the adjoining row of cells, as shewn in *Fig.* 9; *e*, *e* are binding screws, connecting the battery plates with brass strips, *b*, *b*; *f*, *f* are the graphite plates, *g*, *g* the lead heads attached to these, *h*, *h* the plate screws, and *i*, *i* the zinc plates, the latter longer than the graphite elements, in order that they may dip into the recess *k*, filled with mercury, in the bottom of each cell, to keep the zinc plates amalgamated; *m*, *m* are shoulders running longitudinally along the bottom of each cell. *Fig.* 9 shews a plan of a battery of 50 cells, connected up and ready for use; 50 cells is the number which it has been decided to arrange together for work.

Details of stand for firing battery.

Plate LXIII. shews the details of the stand, which is made of iron, for the firing battery of 50 cells. *Fig.* 1 shews a plan of the stand with the cells removed; *Figs.* 2 and 3 shew elevations of each end, and *Fig.* 4, a side elevation of the same, with the plates raised out of the cells. *Fig.* 5 shews a section, through the frame and cells, on the line A B; *Fig.* 6 shews one of the iron rods, used to support the ebonite cells in sections of 10 in the moveable trays. *Fig.* 7 shews a plan of one of the friction wheels, on which the trays run. The plates, attached to their respective ebonite bridges, are arranged to be raised or lowered by means of a crank handle *a*, fitting on the end, *b*, of the axle of a drum *c*, fixed at one end of the frame, and acting through copper wire ropes, *d*, *d*, attached to an iron frame, on which the ends of the ebonite bridges are supported, and passing over a series of pullies, *e*, *e*, *e*, *e*, revolving on iron bars, *f*, *f*, attached to the top of the stand. *g*, *g* are compensating weights

of lead, to enable the plates to be raised or lowered with greater ease and regularity of motion. By this arrangement, the whole number of 50 cells complete, may be raised or lowered together with great ease and facility. *h, h* are the trays, each carrying 10 cells, and when the plates have been raised to the height shown in *Fig.* 3, the trays may be run out from beneath them, for examination or replenishment of the liquid contained in the cells, and run in again with great facility. When it is intended simply to raise the plates out of the liquid, they need not be taken higher than is shown in *Fig.* 4, their ends remaining within the tops of the cells: this is preferable to drawing them entirely out, as it saves the chance of their striking against the tops of the cells, and being thus broken, when they are again lowered, and they are equally clear of the liquid as if they had been raised completely out. The metal frame, on which the ends of the ebonite bridges rest, and which gives motion to the whole, through its connection with the copper wire ropes, *d, d*, is provided with four friction wheels, working into the corners of the frame of the stand, to enable it to be raised and lowered evenly, and without striking, or irregularity of motion.

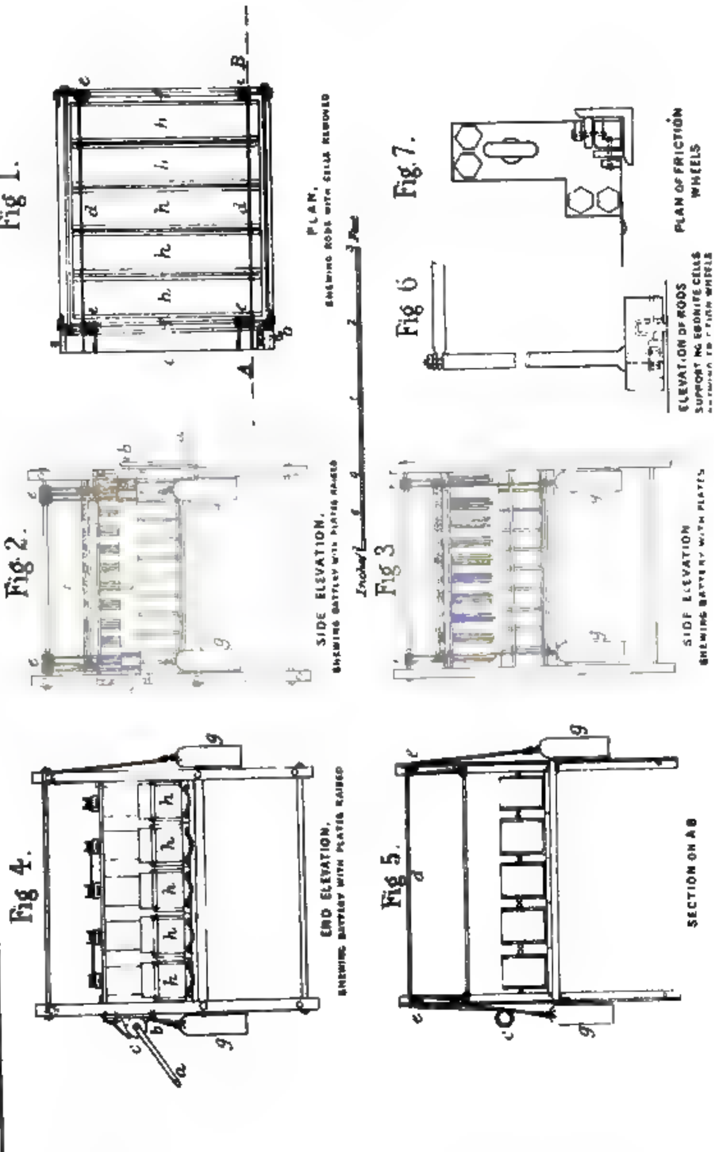
Modification of firing battery, proposed by Qr.-Mr. Sergt. Mathieson, R.E.

This battery possesses one very serious fault, namely, that it polarises very rapidly the moment the battery circuit is closed. In order to obviate this, Qr.-Mr. Sergt. Mathieson, R.E., has proposed the following arrangement, by which the service pattern, (Walker's), firing battery is converted into a modified form of Leclanché.

The zinc plate is taken out and swathed with two layers of soft, coarse, household flannel: in winding the flannel on, it should be drawn tightly round the top of the plate and allowed to remain loose at the bottom. The flannel should then be sewn down the side, thus forming, as it were, a tapering shaped bag, open at the bottom, into which 5 or 6oz. of ground sal ammoniac is then packed, and the bottom securely sewn up; should it now be too thick to pass between the carbon plates, it may be sufficiently flattened, by a gentle blow or two, to enable it to go easily into its place. The three plates, (two of carbon and one of zinc), are next placed in the centre of the ebonite cell, and the whole packed, as tightly as possible, with a mixture of pounded carbon and peroxide of manganese, precisely the same mixture as is used in the ordinary Leclanché battery. Too much care cannot be taken, to ensure that the whole space, between and around the plates, is completely filled with this mixture, when the cells are first made up, so that the particles of carbon may be in contact, one with another, throughout. If this is not the case, the mixture will settle down, after the cells have been some little time in use, leaving vacant spaces between the plates, which, when the battery becomes dry by evaporation, reduce the working surface very materially.

STAND FOR FIRING BATTERY.

FOR 60 CELLS.



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When the battery is required for use, the cells are well saturated with a solution of sal ammoniac, or filled to the extent of a little more than half their depth. With proper treatment, the store of sal ammoniac in the bag will last for many months, and to keep the battery in working order, it will only be necessary to add a little saturated solution of sal ammoniac to the cells every two or three months.

Experiments on a small scale seem to indicate that this battery is likely to be very efficient, as a firing agent for submarine mines. A few further experiments, on a larger scale, are about to be undertaken, and it is probable that they will confirm the favorable results already obtained. It is undoubtedly an improvement on the present firing battery of Walker's form.

Battery for testing.

For testing purposes, the Daniell is the most suitable and convenient form of battery. It is comparatively constant, its electro-motive force is so low, that, with two of its elements, tension fuzes can be tested with perfect safety. The form of Daniell adopted is that known as the Post Office pattern, in which the fragile porous cells of the ordinary form are replaced by porous diaphragms, permanently fixed inside the battery box, which contains 10 cells, the whole of the interior of the box being lined with marine glue. The only addition to the ordinary Post Office pattern, is the provision of extra terminals, in front of the box, to admit of any particular cell or number of cells that may be required, being readily connected up in circuit.

Battery for shutter apparatus.

This arrangement makes this pattern of battery available for use with the shutter apparatus, either on the circuit closer or circuit breaker system. In the latter, the battery has to perform the exhausting office of working with a circuit continuously closed through a comparatively small electrical resistance: even when used for this purpose, however, it will remain in effective working order for a period of 14 days at least. Its electro-motive force, compared with a standard Grove cell, is as 55 to 100, and its internal resistance as 12 to ·08 approximately. The working current on short circuit may be represented, in the case of these two batteries, by ·47 and 135·00. This battery requires very little attention, beyond the occasional addition of a little water, from time to time, as the liquid evaporates, and dropping a few crystals of sulphate of copper at intervals into the compartments containing the copper plates, to keep the solution of sulphate of copper up to that state which is known as *saturated.* No acid is required, though the battery action, when the cells are first made up, may be hastened by an addition of very dilute-acid in the zinc compartments; this, however, exhausts the battery more quickly, and it is not recommended.

Batteries for electric telegraph.

For ordinary telegraphic purposes, one of the most powerful and convenient forms of battery is the Leclanché, and it has been decided by the Torpedo Committee to use these elements

Leclanché.

with the Morse recording instruments, for communication between the observing stations. The line being short, and the coils of one instrument only being in circuit while signalling, it will be sufficient to provide 10 cells with each instrument, and 10 in reserve. The Leclanché battery requires but little attention, and may be allowed to remain undisturbed for months.

The electro-motive force of the Leclanché, compared with Grove's battery, is as 73 to 100 nearly, and its internal resistance is about one ohm. The working current on short circuit compared with a Grove's cell is as 6·66 to 135·00.

Daniell.

Twenty cells, of the form of Daniell's battery already described, are recommended for use, when communicating with a boat by means of the portable Morse sounders, as in this case the instruments are worked with a continuous current, and signals are transmitted by breaking the circuit, for which purpose the Daniell's battery is admirably adapted. The Leclanché battery is, however, also available for this purpose, and would answer very well, though not so well as the Daniell.

Voltaic pile.

For boat service a voltaic pile has been devised by F. Abel, Esq., F.R.S. It is described as follows in the *Report of the Floating Obstruction Committee*:—

Extemporised voltaic pile.

"This battery consists of a series of pairs of zinc and copper discs, or square plates, each pair being separated by a piece of flannel of corresponding size, steeped in a saturated solution of salt acidified with a little vinegar, the pairs being arranged in four piles, connected by strips of metal to each other, and confined between two boards in such a manner that they afford the means of pressing the discs compactly together. The most efficient form of battery is constructed as follows:—

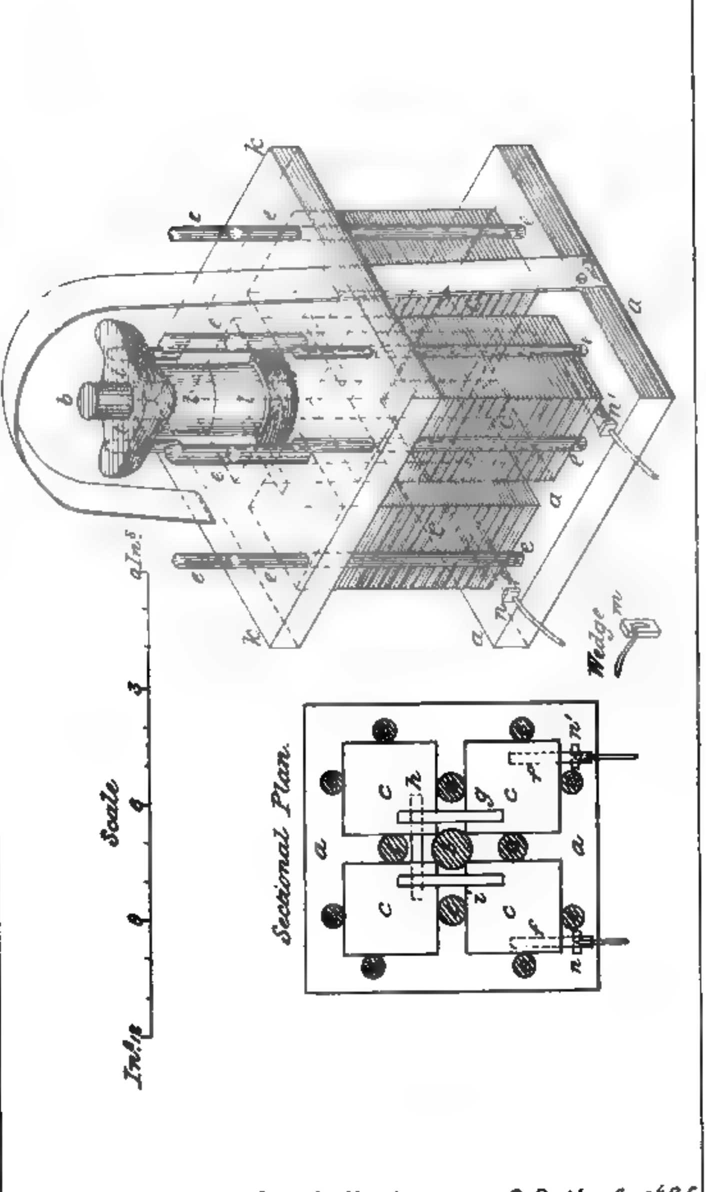
Construction

"A piece of hard dry wood, *a*, *Plate* LXIV., about 7½" square and 1" thick, it is well lacquered or varnished on its upper surface, or coated with a mixture of gutta percha and pitch, or of beeswax, rosin, and pitch. A wooden rod, ¾ of an inch in diameter and 11" in height, with a screw cut upon about 6" inches of its upper end, is fixed vertically into the centre of the wooden slab.

"Around this rod are arranged four piles of zinc and copper plates, *c*, *c*, either square or circular, of 2½" to 2¾" diameter, and which may be cut out of smooth copper and zinc sheets. Eight slight wooden rods or sticks *e*, *e*, 9" in height and about ¼ of an inch in thickness, are loosely fixed into perforations in the board so as to be capable of removal at pleasure, being merely required to support the metal plates during the process of piling them.

"The two poles of the battery *f*, *f*, are formed of two strips of copper, about ¼ of an inch in width, and of sufficient length to reach from the exterior of the board to the centre of one of the piles of plates. One end of each strip of copper is bent downwards, and fixed into a separate small slot cut into the board near one edge."

EXTEMPORISED VOLTAIC PILE.



Lithographed at the S.M.E. Chatham. B. Butler, Corp.l R.E.

"A number of discs of flannel are prepared $\frac{1}{8}''$ less in diameter than the metal plates. They may consist of old blanket or of a double thickness of service cartridge serge, roughly stitched together."

The mode of arranging the battery is as follows:—

Arrangement for action.

"The flannel discs are soaked in a liquid prepared by saturating water with common salt, and adding some vinegar in the proportion of one ounce to a quart of water; they are afterwards squeezed out as dry as possible by the hand before being used. A zinc plate is placed upon one of the strips of copper which lies flat on the board and leads into one of the slots, and a disc of flannel, moistened as described, is placed upon the zinc. A pair of copper and zinc plates is then placed upon the flannel, the copper being undermost; a second flannel disc follows, then a pair of plates as before, and so on until a pile of 30 zinc, 30 flannel, and 30 copper discs has been completed. A precisely similar pile is then constructed by its side, the first plate being, however, zinc in this instance, and the position of the copper and zinc discs in each pair being the opposite of that in the first pile, the zinc being therefore the lower plate. The top disc of pile No. 1 (copper), and the top disc of pile No. 2 (zinc), are then connected by laying a thin strip of copper, *g*, across them. The third pile is now commenced, a thin strip of copper, *h*, having been laid upon the board to connect it with the second pile. A copper plate is taken first this time, as in the case of pile No. 1. Lastly, a fourth pile is commenced by placing a zinc plate upon the strip of copper which constitutes the second pole of the battery, and this pile is built up like No. 2 pile. The top discs of piles No. 3 and 4 are then connected by a strip of copper, *i*.

"A piece of hard wood, *k*, similar to the bottom board, is well coated with pitch composition or varnish on one side, and is provided with a central perforation, through which the screw is to pass, and with holes of sufficient size to allow all the thin rods which support the piles of plates to pass freely through. This board is placed with its coated side downwards upon the piles, and is then pressed upon them by means of wooden nuts *l*, *l*, which are screwed on to the central rod. The plates are thus firmly held in their places, but the pressure applied by means of the screw must not be sufficiently great to squeeze any water out of the flannel discs.

"If there is no workman or lathe at hand to provide the screw and nuts, the pile may be firmly braced together by passing two or three turns of stout cord round the boards, and tightening these cord bands by means of wooden wedges.

Employment.

"To connect the battery with the firing wires, the cleaned end of the conducting wire is inserted into one of the slots containing a pole of the battery, and it is maintained in close contact with the copper strip in that slot by passing a wire round

a small wooden wedge, which is then forced into the slot at *n*. The circuit is completed when required by bringing the return firing wire, (or earth wire), into contact with the strip of copper forming the other pole of the battery, *n*.'

Directions for cleaning it.

"When the battery is taken to pieces, the flannels should be placed in water acidulated with vinegar or oil of vitriol, and, after having soaked for about an hour, they should be washed in pure water and wrung out. The plates of zinc and copper should be thoroughly cleaned by scrubbing them with wet sand."

Working current of battery improved by insulation.

The working force of the current of any voltaic battery or pile is much improved when it, (the battery), stands on a good insulating substance. When practicable, therefore, it is recommended that the whole battery or pile may be arranged to stand upon a sheet of thick crown glass. The reason of the improvement is, that the insulating substance prevents minutely small losses of current, which occur, more or less, in practice, even when batteries have been put together with the utmost care, and which pass to earth without passing through the working circuit, when the battery stands upon any less perfectly insulating material.

The following table gives the internal resistance and comparative electro-motive force of several forms of voltaic battery :—

Name of Battery.	Size of Plates.		Internal resistance of one cell B.A. units	Electro-motive force comparative.
	Copper or Graphite.	Zinc.		
Varley's Daniell...	22″ × 2″ spiral.	5″ × 1¾″	10	911*
Muirhead's do. ...	3½″ × 4″	3½″ × 4 ″	7	880*
Schaw's do. ...	4″ × ¾″	3½″ × ¾″	10	858*
Woolaston's Sand	3½″ × 4½″	3½″ × 4½″	15	835
Mariè Davey	6″ × 1¾″	6″ long ½″ diam.	½	1220
Leclanchè	79″ × 1¾″	6″ long 5/16″ diam.	1	1200

NOTE.—These results have been obtained from cells freshly made up; the experiments were tried at 6 hours, 30 hours, and 54 hours after the batteries were put together.

* The electro-motive force of these different forms of Daniell's battery should be all the same, if metals of equal purity were employed in each, and the solutions were in the same condition.

FIRING BY CROSS BEARINGS.

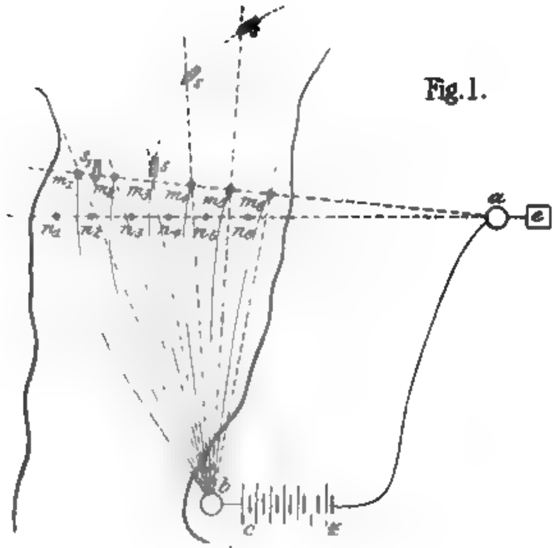


Fig. 1.

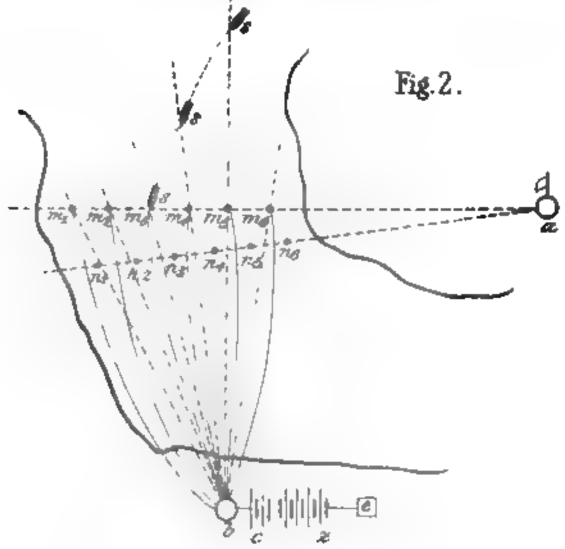


Fig. 2.

Lithographed at the S M E, Chatham. *B Butler, Corp^l R E.*

CHAPTER XI.

Closing Electrical Circuit.

Having got our mines placed in position, established the conducting cables to connect them with our testing room, and selected the most approved form of battery or igniting agent, it now becomes necessary to discuss how any particular charge of a group may be fired at the right moment. This may be done at will, the position of the ship being determined by intersection, or the vessel herself may be made to complete the circuit by striking a circuit closer.

Firing by cross bearings, or intersections

In firing at will, the vessel's position being determined by intersection, several expedients may be adopted.

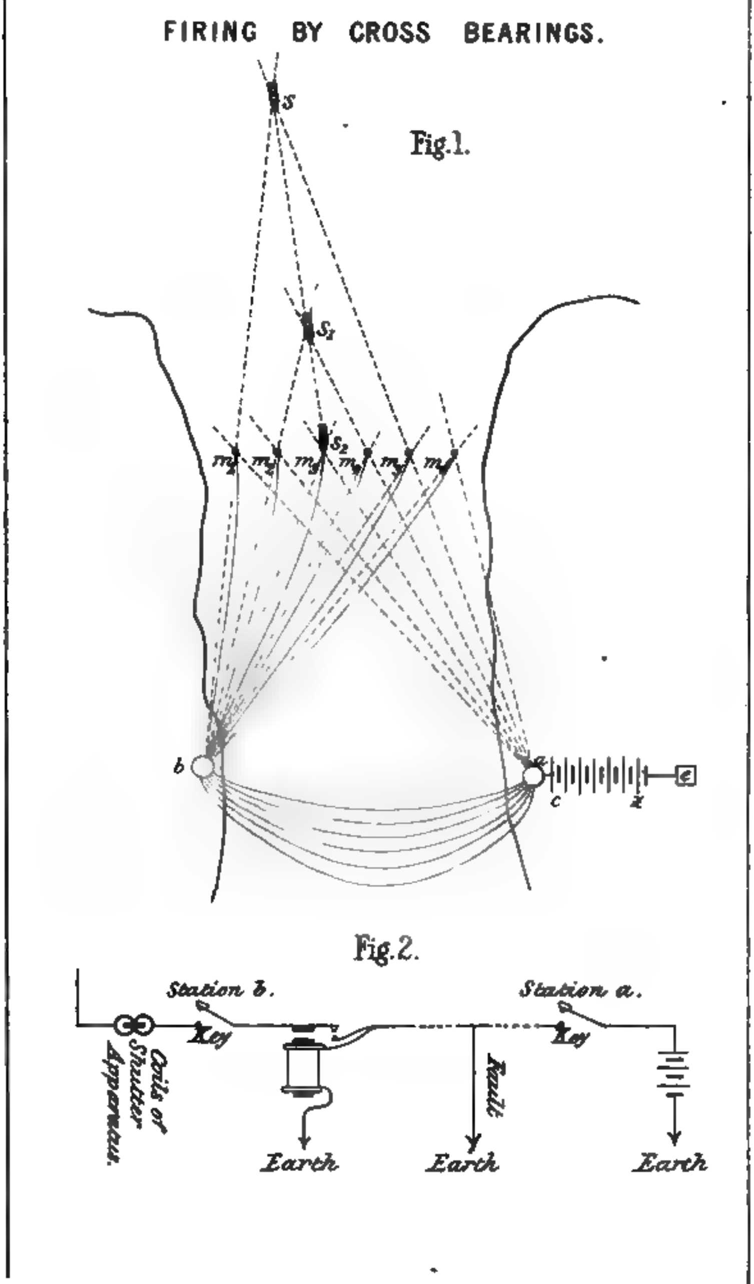
The most simple is that in which an observer can be placed on the prolongation of a line of mines, as at *a*, *Plate* LXV., *Fig.* 1, commanding the mines m_1, m_2, &c., and on the prolongation of their direction, a second observer being stationed at the point *b*; *c z* represents the firing battery, which should be placed at the station *b*. One pole of the firing battery should be connected with the terminal of an ordinary firing key, while the other should be attached to an electric cable connecting the two stations *a* and *b*. The electric cable connecting the two stations *a* and *b*, should be attached to one terminal of a firing key at the station *a*, while the other terminal of the firing key should be connected to earth at the point *e*. Till the key at *a* is pressed down, and one pole of the battery is thus put to earth, no current can circulate, but directly it is pressed down, the circuit is completed up to the station *b*. From the station *b*, a series of electrical cables *b* m_1, *b* m_2, &c., attached to a series of contact points, perfectly distinct and carefully insulated from each other, pass to the mines m_1, m_2, &c., through the fuzes in connection with them and to earth. At this second station *b*, we have a second break in the electrical circuit, and it is easily seen that, in order to pass the current and fire any particular fuze, both these breaks must be bridged over, under which circumstances the circuit of the battery will be completed and the mine fired. Let us now suppose a vessel to be approaching this line of mines, as her bow passed across the production of the line *b* m_5 the observer at *b* would put

down key No. 5, in connection with m_5, but as the ship had not come into the line from a, passing through the line of mines, the observer at a would not put down his key, a break would still exist in the circuit, and no current could pass to fire the mine. When the vessel had passed the line $b\ m_5$, the observer at b would allow the key to spring up and break the connection. As the vessel passed the line $b\ m_4$, the observer at b would press down key No. 4, but as she would still not be on the intersection of the lines $b\ m_4$ and $a\ m_4$, the same result as before would be obtained, and the charge m_4 would not be fired. Let us now suppose, that she passes on in her course till she arrives over the mine m_3; in this position she would be on the intersection of the two visual lines $a\ m_3$ and $b\ m_3$: the observers at a and b would in this case both put down their respective keys simultaneously, the circuit of the battery would be completed through the mine m_3, and that mine would be fired. In the case of a vessel passing through an interval between any two mines, at such a distance as to be out of the radius of destructive effect of either of them, as for example at the point s_1 between m_1 and m_2, it is easily seen that at the moment of passing the line $a\ m_1$, when the observer at a would have his key down, she would not be on the production of any of the lines $b\ m_1$ $b\ m_2$, &c., and as the observer at b would not, under such circumstances, press down his key, she would pass on to the second line n_1 n_2, &c., and having passed safely through the interval of the first line, would stand a good chance of coming within striking distance of one of the mines of the second. For this second line n_1 n_2, &c. a similar but separate arrangement should be prepared. One pole of the firing battery, which should be placed at the station b, should be connected with the terminal of an ordinary firing key, while the other should be attached to an electric cable, connecting the two stations a and b. The electric cable, connecting the two stations a and b, should be connected to one terminal of a firing key at a, while the other terminal of the firing key should be connected to earth at the point e.

Firing by a preconcerted signal at one station.

A modification of this plan may occasionally be adopted, by employing a preconcerted signal at the point a, when the bow of a vessel came on the line $a\ m_1$. For instance, if, when the bow of the vessel s arrived on the line $a\ m_3$, a flag were raised at the point a, the observer at b would instantly notice whether she was on any of the lines of sight passing over his mines, and if she were would at once press down the key corresponding therewith, as No. 3, shewn in *Plate* LXV., *Fig*. 2. Directly she had passed the line $a\ m_1$ the flag at a should be dropped, as she would then be safe so far as that line was concerned. This latter system requires great coolness and nerve on the part of the observer at b, as he has two things to do—viz., to watch the vessel passing across his intersections, and to be on the alert to

FIRING BY CROSS BEARINGS.



graphed at the S.M.E. Chatham B. Butler, Corpl R.E.

receive the signal from a. In such a case, it has been found best to employ two men at station b, one exclusively to watch the station a, and on the flag being raised to give the word "fire," and on the flag being dropped to give the word "stop," the second man would keep his eye on the vessel, and be ready to fire the right mine at the right moment. A separate signal flag and firing arrangement would, as before, be required for the next line n_1 n_2, &c. of mines.

Arrangement of separate intersections for each mine.

As in many cases, it would not be practicable to have a station in such a position as a so far advanced towards the point of attack, with the corresponding danger of being cut off by an enemy, another combination becomes necessary; this is shewn in *Plate* LXVI., *Fig.* 1. Two stations a and b, well within the defensive works, are selected in such a position that the lines, passing from them over each charge, shall intersect in such a manner as to give, what is termed, well conditioned triangles, or in other words that they shall not intersect each other at too oblique an angle. The battery is placed at the point a, one pole being attached to earth, while the other is connected with a centre from which radiate a series of contact keys. From the studs or contact points of these keys a series of cables, corresponding in number to the charges in position, pass to the similar contact points of a set of keys at the station b, and from the pivots of the keys at b an electric cable passes to each charge. In this case, therefore, each charge has a separate key at station a, and a separate key at station b, each perfectly distinct from every other, and well insulated therefrom, but the whole culminating at a, in the single battery o s. In each circuit, corresponding to any particular mine, there are therefore two breaks—one at its particular contact key at the station a, and the other at its corresponding key at station b,—and till these breaks are bridged over, by pressing down the contact keys simultaneously, the circuit of the battery will not be closed, and the mine will not be fired. In this way, it is easily seen that if, for example, key No. 1 is put down at the station a, and key No. 2 at station b, there still remains a break in each circuit; in circuit No. 1 at station b, and in circuit No. 2 at station a, and neither of these mines will be fired. The object of this arrangement is easily seen if we trace the course of the vessel s, approaching the line of mines. She first comes on the line of m_5 from station a, and simultaneously on that of m_1 from station b, the observer at a puts down key No. 5, and the observer at b key No. 1, without of course firing any mine; again, as she reaches the position s_1, the observer at a would put down key No. 4, and the observer at b key No. 2, without any circuit being closed. Let us now suppose her to reach the point s_2, where the lines from both stations over the charge m_3 intersect; both observers would now put down keys No. 3 simultaneously, the circuit of mine m_3,

would be closed, the charge would be fired, and the vessel struck.

Pickets may be used for intersections at short distances.

In carrying on the system above described, it has been found that with a series of small wooden pickets, placed in a radiating form from a central point of observation, at a distance of about 20 feet, and with pieces of twine passing from the centre over each picket in the directions of the charges, to indicate the bearings more accurately, very good practice has been obtained, all the charges having, at a distance of nearly half a mile, been exploded within a radius of six feet of the object aimed at. The observer, with his eye at the central picket and right hand on the contact keys, puts the corresponding one down as the object passes the line indicating the bearing of each. A man soon learns, by practice, the distance he may allow on one side or other of the bearing line, and with ordinary care and nerve is soon able to make contact at the right moment. There is no doubt, however, that on actual service the steadiest and coolest men would be required to work such a system effectually.

Set of Firing keys.

The following is a description of the firing keys approved, and shewn in plan and section in *Plate* LXVII., *Figs.* 1, 2, and 3. The apparatus consists of a strong wooden frame *a*, of convenient form for attachment to a table, for which purpose holes *b*, *b* are provided to admit a pair of screws: on this frame a series of keys *c*, *c*, *c*, are arranged at convenient intervals. These keys consist of a strong brass spring, firmly screwed to a series of brass plates *d*, *d*, *d*, on the front of the wooden frame: copper wires *e*, *e*, *e*, pass through the woodwork from the brass plates *d*, *d*, *d*, to afford facilities for electrical connections, for which purpose a series of binding screws *f*, *f*, *f*, are provided, one for each. The inner ends of the keys are supplied with an ebonite knob, to insulate the operator's hand while in use, below which they are of convenient form to make contact, when depressed, with a series of metallic points *g*, *g*, *g*, from which wires *h*, *h*, *h*, similar to those in front, pass downwards through the woodwork: these wires are similarly provided with binding screws *f*, *f*, *f*, to facilitate electrical connections.

Single firing key.

Under certain circumstances, a single firing key only would be required. For this purpose the form shewn in *Plate* LXVII., *Fig.* 4, has been approved. This, like the others, consists of a brass spring *a*, with an ebonite handle or knob, arranged on an ebonite block. Two binding screws *b*, *b*, one in connection with the front of the key, and the other with the contact point under its handle, are placed at one end of the apparatus. An ebonite safety guard *c*, is attached: this is capable of being turned under the key, between the contact point and the key itself, (so as to prevent any chance of its depression by accident, which might fire a mine at the wrong moment), or it may be pushed on one

FIRING KEYS.

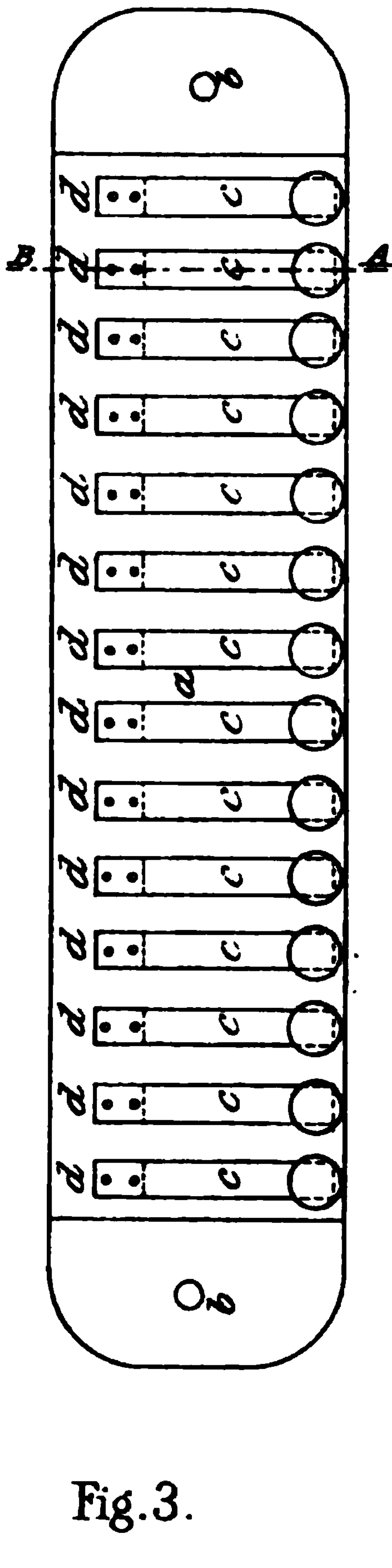


Fig. 1.

Plan.

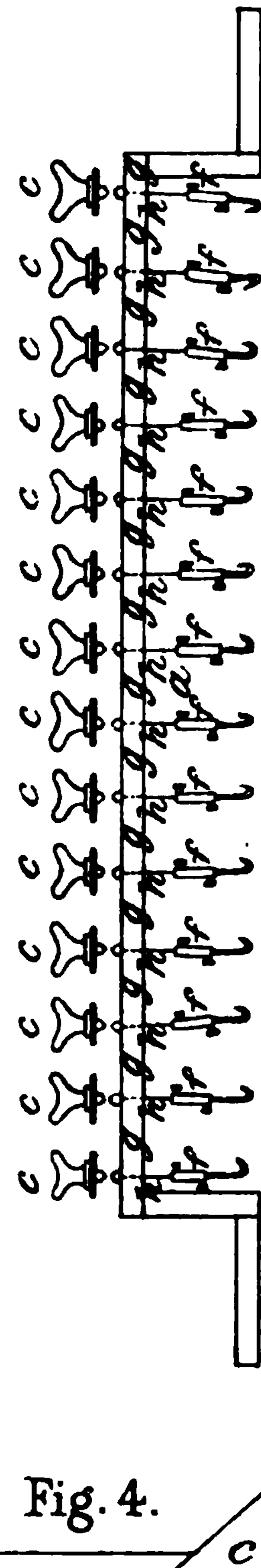
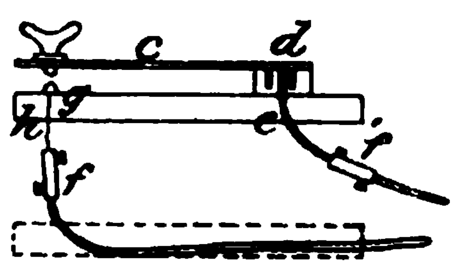


Fig. 2.

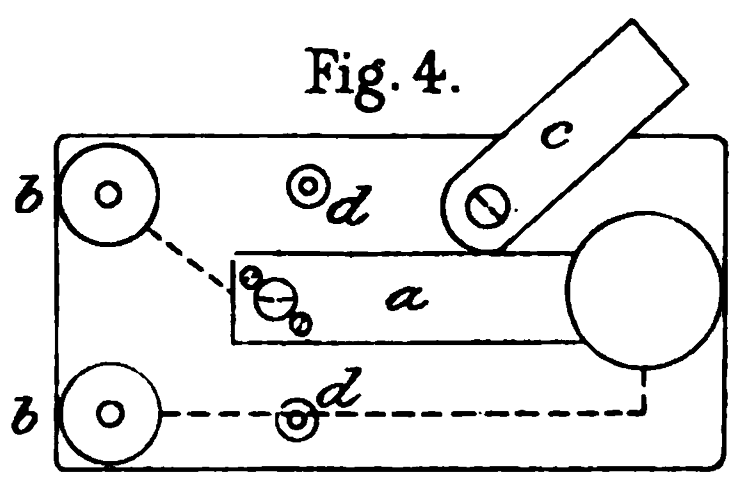
Sectional Elevation.

Fig. 3.



Section on A B.

Fig. 4.



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side when the key is required for use. It is shewn in this latter position in *Fig.* 4. Screw holes *d*, *d*, are provided for the attachment of the apparatus to a table if required. This form of key is adapted not only for firing purposes, but for any connections which may be required in testing, &c.

Connections of keys for work.

In the combination shewn in *Plate* LXV., *Fig.* 1, a single key only would be required, for each line of mines, at the observing station *a*; this would be of the form shewn in *Plate* LXVII., *Fig.* 4. One binding screw of this key would be connected to a zinc earth plate, while the other would be attached to one core of the electric cable, connecting the observing with the firing station. At the firing station *b*, the other extremity of the same core would be connected to one pole of the firing battery, while from the other pole a series of electrical connections would be made, one to each of the binding screws in the rear of a set of firing keys, similar to those shewn in *Plate* LXVII., *Fig.* 1, corresponding to each mine of the line to be fired by intersection. By this combination, when a vessel arrived on the line, the observer at station *a* would press down his key, putting one pole of the battery to earth, while the observer at station *b* would put down the key corresponding to the particular mine, in alignment from his station, with the ship. It is evident that no mine in the line could be fired, unless both keys were down simultaneously, and this only would occur if a vessel were on the line of mines as seen from station *a*, and on the alignment of any particular mine, as seen from station *b*, at the same moment. For the arrangement shewn in *Plate* LXV., *Fig.* 2, only one set of keys would be required, the battery being connected to the whole of the rear binding screws, with the separate cables radiating from the front. If used in the combination shewn in *Plate* LXVI., *Fig.* 1, two complete sets of keys would be required, arranged as follows. At station *a*, one pole of the battery would be put to earth, while the other would be connected, by a series of radiating wires, to the rear terminals of a set of firing keys, one key being provided for each mine. The front terminals of the firing keys, would be attached to the extremities of a series of insulated cores, connecting the two stations, while the other extremities of these cores would be connected, at station *b*, to the rear terminals of another set of keys. From the front terminals of these latter would radiate the series of insulated cores, leading to the several mines, in the line for which this system was arranged.

In this case, it would be necessary to provide a second firing battery at station *b*, for use with the mines when they are to be made self-acting, which would be necessary if station *a* fell into the enemy's hands.

The arrangements described so far, are of the very simplest nature, for firing directly by means of the firing keys, without

the intervention of the shutter signalling apparatus. When this latter is used, the self-acting system would be employed simultaneously with that of firing by intersections, in a manner to be hereafter described.

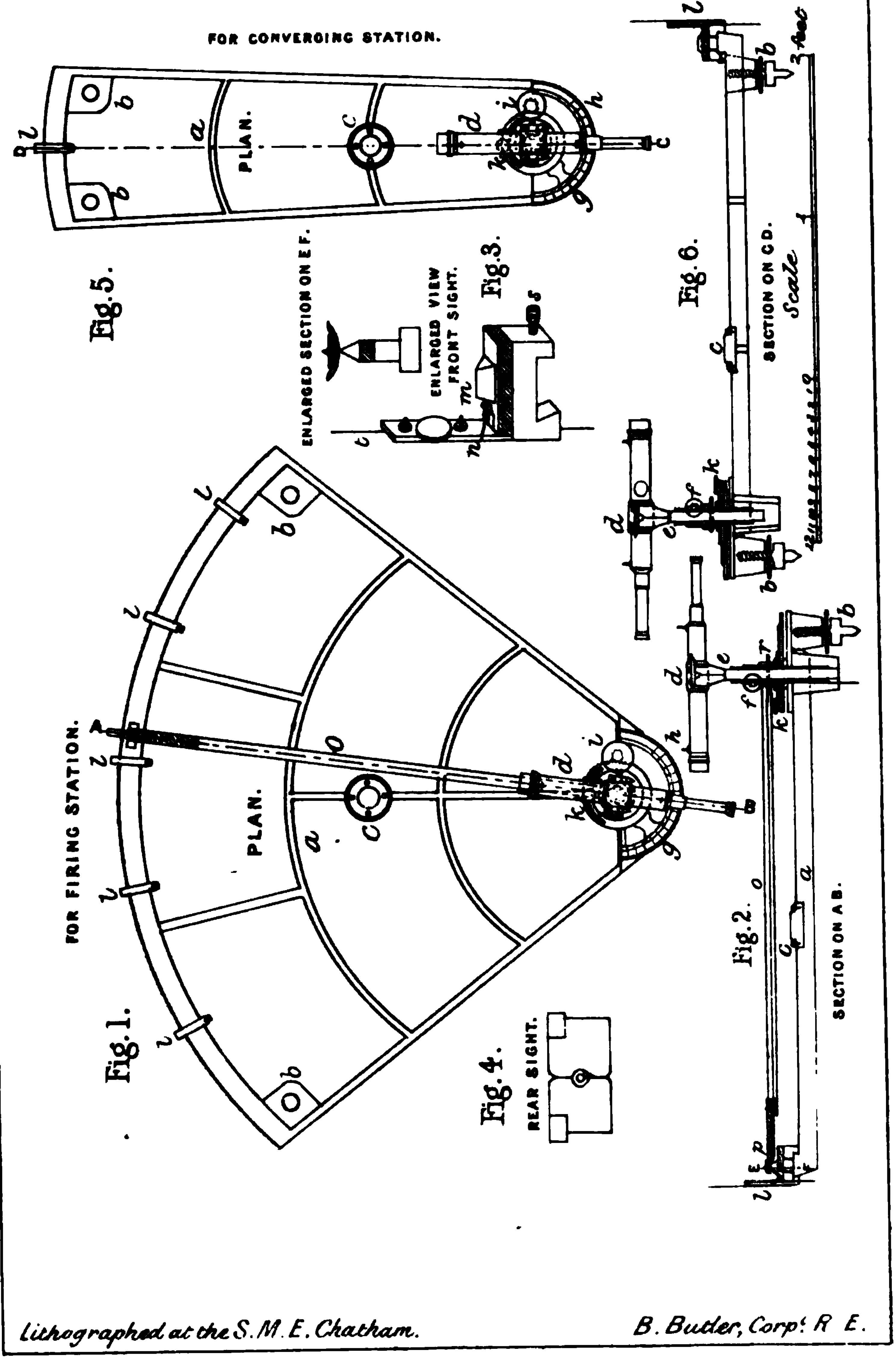
In using the keys it is necessary to press them firmly down and hold them firmly down, in order to ensure good contact at the proper moment.

To work efficiently, it does not seem desirable that more than 12 keys should be entrusted to the management of any one man.

Telescopic firing keys.

The system of pickets above described, for giving the bearings, might probably be used effectually up to half a mile, but at greater distances a more accurate means of obtaining the intersections becomes necessary; the pickets have, moreover, the disadvantage of being easily disturbed, and difficult to replace in an accurate position, if once moved. In order, as far as possible, to obviate these defects, a telescope, with cross wires, has been mounted in connection with a series of contact points and with a graduated arc and vernier, as shewn in *Plate* LXVIII. It consists of a cast iron frame *a*, with three feet *b*, *b*, *b*, *Figs.* 1 and 2, provided with levelling screws; a circular level *c* is attached to this frame, which indicates, with sufficient accuracy, when it is level. *d* is a telescope, provided with one horizontal and three vertical cross wires, supported on Ys, so as to admit of vertical motion, and attached to an upright *e*. The telescope may be raised or lowered by means of a milled-headed screw *f*, working in a rack and pinion arrangement. The top of the telescope is provided with sights, in a vertical plane passing through the axis of the instrument. The telescope is rigidly connected to a vernier *g*, traversing over a graduated arc *h*: the telescope and vernier may be moved rapidly and synchronously in either direction, by means of a rack and pinion arrangement *i*, and a clamp *k* is provided, to hold the telescope and vernier in a stationary position when required: it is necessary to be careful, not to attempt to turn the rack and pinion *i* when the instrument is clamped, as such an operation would be very liable to injure the teeth of the connecting pinions. The outer rim of the frame *a* is made smooth, and on it sights *l*, *l*, *l*, shewn on a larger scale in *Fig.* 3, are attached to give the directions of the several mines in connection with the instrument. These sights are each provided with a brass point of V form *m* and a binding screw *n*, in metallic connection with each other but insulated carefully from the remainder of the metal of the sight: a brass tube *o*, rigidly connected to, and moving with, the upright carrying the telescope *d*, projects in front of this latter. A brass spring *p*, attached to the lower portion of the outer extremity of this tube, is so arranged as to make contact with the V contact points *m* on the sights, by means of a projection of corresponding shape fitted below it. Metallic connection is established between this

TELESCOPIC, OBSERVING AND FIRING ARCS.



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projection and a binding screw *r*, on the upright carrying the telescope, by means of an insulated wire, the projection and binding screw being themselves carefully insulated from the adjoining metal of the instrument. *Fig.* 3 shews an enlarged view of the form of sight: in addition to the V projection *m* and binding screw *n*, it is fitted with a capstan-headed screw *s*, for attaching it to the outer rim of the frame, and a thin wire upright *t*, for giving the alignment of the mine, to which also a disc is attached, on which the number of the mine should be placed, after the latter has been put in position and its direction taken.

The telescope attached to this apparatus, must always be used during the operation of putting the mines in position, in order that their bearings may be very accurately taken and registered, by means of the vernier, from the graduated arc. When the distance to the mines is within a mile, a sight or eye piece has been provided, to take the place of the telescope for following the motions of a vessel. The details of this sight are shewn in *Fig.* 4: it consists simply of a small hole, in the centre of a metal plate, through which the eye may be directed along the alignment given by the pin of the front sight, and so on towards the position of the mines. It is fitted with projections, of trunnion form, similar to those of the telescope, to carry it, in proper position, in the Ys of the instrument. When the distance to the mines is more than a mile, the telescope itself should be used for following the motions of a ship, the cross wires giving the necessary information as to her position with regard to the mine. Some persons prefer to use the telescope for all distances: this is quite a matter of taste, and each may be left to follow his own fancy in this particular.

Eye piece.

In the combination shewn in *Plate* LXV., *Fig.* 1, a single fixed telescope with its axis directed very accurately on the line of mines, would be required, for each row in the system, at the converging station *a*: this would be used in connection with a single key of the form shewn in *Plate* LXVII., *Fig.* 4: one terminal of the key would be put to earth, while the other would be attached to the insulated core connecting the two stations. At station *b*, (the firing station), each row of mines must be provided with a telescopic firing arc of the form shewn in *Plate* LXVIII. The core connecting station *a*, would be attached to one pole of the firing battery, while the other would be connected to one terminal of a firing key, the other terminal of which would be connected to the binding screw *r*, *Fig.* 2, and the electric cables, connecting each mine, would radiate from the front contacts, being attached to these by means of the binding screw *n*, *Fig.* 3. The action of the apparatus is easily understood. Should a hostile vessel arrive upon the line of mines as seen from station *a*, the observer at that station would immediately put

Connections of instrument for use.

down his firing key when her bow touched the line, and keep it down till her stern had passed, thus connecting one pole of the firing battery to earth; the observer at station *b* would look along his sights, turning the winch *i*, till the front of the arm *o* rested on the particular sight of the mine nearest the line in which the vessel was approaching, and as soon as she arrived on, or sufficiently near, the line, as indicated by his sights, he would put down his firing key, and keep it down as long as she remained within striking distance from that particular mine, as seen from his station. It is easily understood, that the battery circuit would only be closed and the mine exploded, when the keys at both stations were down simultaneously, and this could only occur when a vessel was within range of one of the mines, as seen from station *b*, and on the line, as seen from station *a*: she would thus necessarily be within range of the mine fired.

Combination where two firing arcs are required.

In the case shewn in *Plate* LXVI., *Fig.* 1, a telescopic firing arc would be required at each station. At *a*, one pole of the firing battery would be put to earth, while the other would be attached to the binding screw *r*, *Fig* 2, *Plate* LXVIII. of the firing arc, with the firing key intervening to form the necessary break in the circuit. The front sights *l*, *l*, *l*, of the firing arc, would be attached to the separate insulated conductors connecting the two stations. At station *b*, *Plate* LXVI., *Fig.* 1, each conductor, connecting the two stations, would be attached to the rear terminal of a set of firing keys, of the form shewn in *Fig.* 1, *Plate* LXVII, while the corresponding front terminals of the same, would be attached, one to each line connecting the mines. The telescopic firing arc at station *b*, would in this case be used for observing purposes only: the observer would notice the number of any particular mine, as indicated on the front sight of the firing arc, and would put down the key with the corresponding number, if the vessel approached within range of such mine, as indicated from his station. As before described, if the keys at both stations, corresponding to any particular mine, were down simultaneously, both breaks in the circuit would be bridged over, and that mine would be fired, and this could never occur, except by accident, unless the vessel was within range of the mine in question.

Combination of firing arc with shutter signalling apparatus.

This method of firing by intersection, may be employed in connection with the shutter signalling apparatus. The principle on which this is done is simply to connect the firing arc and the corresponding fixed telescope, in such a way as to close the circuit of the signalling battery attached to the shutter apparatus, through any particular coil, corresponding to a mine to be fired: to arrange it, in fact, so as to perform the work ordinarily done by the self-acting, circuit closer. Under these circumstances the shutter would be dropped, the firing battery thrown into circuit, and the mine fired. The details of the connections for this mode of firing shall be given, when the

construction of the shutter signalling apparatus has been explained.

Simplicity is essential in all arrangements for firing by cross bearings.

It has been suggested that each mine, in the combination shewn in *Plate* LXVI., *Fig.* 1, should be provided with two fixed telescopes, one at each of the stations *a* and *b*. In this way an observer would have but one object to engage his attention, and but one duty to perform, viz., to put his key down when a vessel arrived on the line of his own particular mine. There is no doubt, that simplicity of arrangement is most essential in firing by visual intersections, and it is very probable that if several vessels were simultaneously approaching a line of mines, which were connected with a telescopic or other arrangement, in which one man had charge of several firing keys, he might be engaged in observing one vessel, while his fellow workman was directing his instrument on another, and many ships might thus pass through uninjured. It unquestionably requires much more dexterity, nerve, and training to work a number of keys, combined with a moveable telescope in one instrument, than to watch a vessel approaching a mine, on which a single, fixed telescope was directed, and to put down a single key on her passing the cross wires. Experiment has, however, proved that, with a proper system of telegraphic communication between the observing stations, the arrangement of a single telescope and key for each line at one station, and a telescopic firing arc for each line at the other, answers very well, and that, under such circumstances, a vessel would rarely escape.

Good insulation essential in the conductor used to connect stations in firing by intersection.

In any combination for firing by cross bearings, it is very essential that the conductor in the firing circuit, connecting the two stations, should be very well insulated. The reason of this is obvious: if, for example, a fault existed in the insulation of the conductor between the stations *a* and *b*, *Plate* LXV., *Fig.* 1, the depression of a key at station *b* would at once close the circuit, through the fuze, whether the key at station *a* was down or not, and if the fault in the cable exposed a sufficient surface of metal to form a moderately good earth connection, the mine might be fired prematurely. It is, therefore, necessary to test the insulation of the connecting electric cable very carefully, and, in doing so, the quality of its conductivity must not be overlooked.

Arrangement proposed by Major Malcolm, R.E.

In order to obviate the chance of a premature explosion under the circumstances mentioned, it has been proposed by Major Malcolm, R.E., to place a battery, as shewn in *Plate* LXVI., *Fig.* 2, between the key and earth connection at station *a*, and to introduce an electro-magnet into the main circuit, between the key and electric cable connecting the two stations, at station *b*, arranging the armature of this electro-magnet in such a way that it shall cover a break in the main circuit: when attracted it should bridge over the break, and when not attracted to the electro-magnet

side when the key is required for use. It is shewn in this latter position in *Fig.* 4. Screw holes *d*, *d*, are provided for the attachment of the apparatus to a table if required. This form of key is adapted not only for firing purposes, but for any connections which may be required in testing, &c.

Connections of keys for work.

In the combination shewn in *Plate* LXV., *Fig.* 1, a single key only would be required, for each line of mines, at the observing station *a*; this would be of the form shewn in *Plate* LXVII., *Fig.* 4. One binding screw of this key would be connected to a zinc earth plate, while the other would be attached to one core of the electric cable, connecting the observing with the firing station. At the firing station *b*, the other extremity of the same core would be connected to one pole of the firing battery, while from the other pole a series of electrical connections would be made, one to each of the binding screws in the rear of a set of firing keys, similar to those shewn in *Plate* LXVII., *Fig.* 1, corresponding to each mine of the line to be fired by intersection. By this combination, when a vessel arrived on the line, the observer at station *a* would press down his key, putting one pole of the battery to earth, while the observer at station *b* would put down the key corresponding to the particular mine, in alignment from his station, with the ship. It is evident that no mine in the line could be fired, unless both keys were down simultaneously, and this only would occur if a vessel were on the line of mines as seen from station *a*, and on the alignment of any particular mine, as seen from station *b*, at the same moment. For the arrangement shewn in *Plate* LXV., *Fig.* 2, only one set of keys would be required, the battery being connected to the whole of the rear binding screws, with the separate cables radiating from the front. If used in the combination shewn in *Plate* LXVI., *Fig.* 1, two complete sets of keys would be required, arranged as follows. At station *a*, one pole of the battery would be put to earth, while the other would be connected, by a series of radiating wires, to the rear terminals of a set of firing keys, one key being provided for each mine. The front terminals of the firing keys, would be attached to the extremities of a series of insulated cores, connecting the two stations, while the other extremities of these cores would be connected, at station *b*, to the rear terminals of another set of keys. From the front terminals of these latter would radiate the series of insulated cores, leading to the several mines, in the line for which this system was arranged.

In this case, it would be necessary to provide a second firing battery at station *b*, for use with the mines when they are to be made self-acting, which would be necessary if station *a* fell into the enemy's hands.

The arrangements described so far, are of the very simplest nature, for firing directly by means of the firing keys, without

the break should exist in the circuit. In this combination, the electro-magnet, being connected to earth and not in direct circuit with the key at station *b*, could only be formed when the key at station *a* was depressed. Under these conditions, if a considerable fault existed in the electric cable connecting the two stations, a proportion of the current of the battery in connection with the electro-magnet, would pass through it to earth, and the loss thus occasioned might be so great, as to prevent a sufficient current being circulated, to pass through the coils and form an electro-magnet of sufficient power to attract the armature. In such a case the mine would not be fired, but it could not possibly be fired prematurely. This arrangement might easily be employed with the firing battery directly in circuit, if a little care were used, as, for example, in the case shewn in *Plate* LXV., *Fig.* 1, the action of the armature, in connection with the electro-magnet at station *b* might be made to transmit a signal that the vessel was passing the line of the mines, and the observer at station *b* should not put his key down till that signal had been received. In this way the system would work very effectively. It would, of course, always be desirable to replace a defective cable, between stations *a* and *b*, by a good one, as soon as possible, but if time were not available for such a operation, it would be comparatively easy so to regulate the battery power at station *a*, as to form an electro-magnet at station *b*, even through a defective electric cable.

Siemens' range finder. Messrs. Siemens, Brothers, of Charlton, have devised a range finder, which might be very usefully employed, in connection with a system of submarine mines to be fired by judgement. It consists of 3 parts: 1st, a telescope with cross wires, to which an arm, in the same vertical plane as its axis, is rigidly attached. Motion is given to the telescope and arm by means of a milled-headed screw, by which the two may be made to traverse together, either to the right or to the left, to follow any moving object; 2nd, a plan, the surface of which is divided into a series of squares or rectangles, each bearing a number for identification, so that in this way the transmission of a number, of four figures,* gives the position of a moving object, at any particular moment, with references to the plan; and 3rd, a telescope, with cross wires, similar to the first, in connection with the armature of a magneto-induction apparatus: when this telescope is turned in either direction, by means of a winch, a series of alternately direct and reversed currents is transmitted along an insulated

* The mode adopted is to divide each side of the plan into 10 equal parts, and to subdivide each side of the squares or rectangles thus obtained, again into 10 equal parts: the identification of the place of any object, in relative position on the plan, is thus quickly given by means of the four figures corresponding to the 10 main divisions on the sides of the plan, and the 10 subdivisions of each square or rectangle.

telegraph line, which puts in motion an armature, like the escapement of a clock, playing between the horns of an electro-magnet, which gives motion to a long, light, aluminium arm; which is arranged to move parallel to the axis of the telescope, in connection with the magneto-induction apparatus. In order to secure synchronous motion in either direction, as the telescope may be required to traverse to the right or left, two conducting lines and two electro-magnets are employed, one combination to transmit a series of currents to act on the aluminium arm, causing it to traverse in one direction, the other causing it to traverse in the opposite direction.

The first telescope, with the fixed arm, may be placed at one end of a base, the telescope pivoted at the point, on a plan of any given scale, representing the end of that base, and the arm traversing over the plan from that point, as a centre of revolution. The second telescope, with its attached magneto-induction apparatus, would be placed at the other end of the base, and would be connected with the pivot of the aluminium arm and its electro-magnetic, motive arrangement, by two insulated wires. The aluminium arm should be pivoted at that point on the plan, representing the position of the second telescope at the distant extremity of the base. It is thus easily understood, that if the two telescopes are directed at the same moment on a moving object from the two extremities of the actual base, while the two arms are in a position on the plan, parallel to the axes of the telescopes and pivotting on the points representing the extremities of the base on plan, the position of the moving object will be at the intersection of the two indicating arms: these will moreover always cross each other over one of the squares or rectangles, into which the plan is divided, and thus give the means of identifying, with great facility, the position of the moving object on any other plan, on any scale, on which similar squares are marked. In the event of the distance of an object being so great, that the two arms do not absolutely intersect, Messrs. Siemen's have a scale attached to the apparatus, beneath the aluminium arm, by means of which the distance may still be found by similar triangles. The second telescope is fitted with a marked point and the aluminium arm with a corresponding line, which, in conjunction with a simple apparatus for disconnecting the latter from the electrical circuit, gives the means of adjusting the two, so that they may start from an initial position, with the axis of the telescope parallel to the side of the aluminium arm.

Siemens' range finder adopted by Prussian government.

This apparatus has been adopted by the Prussians, for use with their system of submarine mines to be fired by judgement, and they report very favourably of its performances. It is very desirable that it should be tried practically, under precisely similar circumstances to those which would occur on service, and in comparison with other systems of a similar nature. In

making the trial, the system should be tested to ascertain how slowly the magneto-induction apparatus could be worked, without producing a cessation of motion in the aluminium arm: also what amount of fault in the insulation of the connecting line wires, would so reduce the current transmitted, as to prevent an effective action on the part of the electro-magnets of the escapement, in connection with the aluminium indicating arm. The resistance of the fault could, if necessary, be very accurately measured, by means of a set of resistance coils and Wheatstone's bridge. The price of one instrument complete is £130. A single one would answer for a very large number of submarine mines, and would be equally available for determining ranges for Artillery practice. It possesses the advantage of being capable of being used away, at any distance, from batteries and consequently well clear of the smoke and concussion produced by guns in action. The position of any moving object might be telegraphed, simultaneously, to any number of gun batteries or to the observing station, from which any system of submarine mines was controlled, if these were placed in electrical communication with the station where the plan and apparatus existed.

Mechanical circuit closers.

We now come to the different modes of firing electrical submarine mines mechanically, that is to say by an arrangement through which the vessel herself closes the circuit, by means of an apparatus called a circuit closer.

A great number of different forms of this instrument have been made, each possessing certain advantages.

Austrian circuit closer.

In the Austrian section of the Paris Exhibition of 1867, a circuit closer was exhibited, in connection with the submarine mines.

In this system, the submarine mine and circuit closer are in the same case. The details of the circuit closer are shewn in *Plate* LXIX, *Fig.* 1: *b*, *b*, *b* are the buffers, held in position by strong brass springs, the openings through which they pass being kept water-tight by means of strong macintosh cloth; when pressed in they would come in contact with, and cause to revolve a brass ratchet wheel *g*, also kept in position by a strong spring.

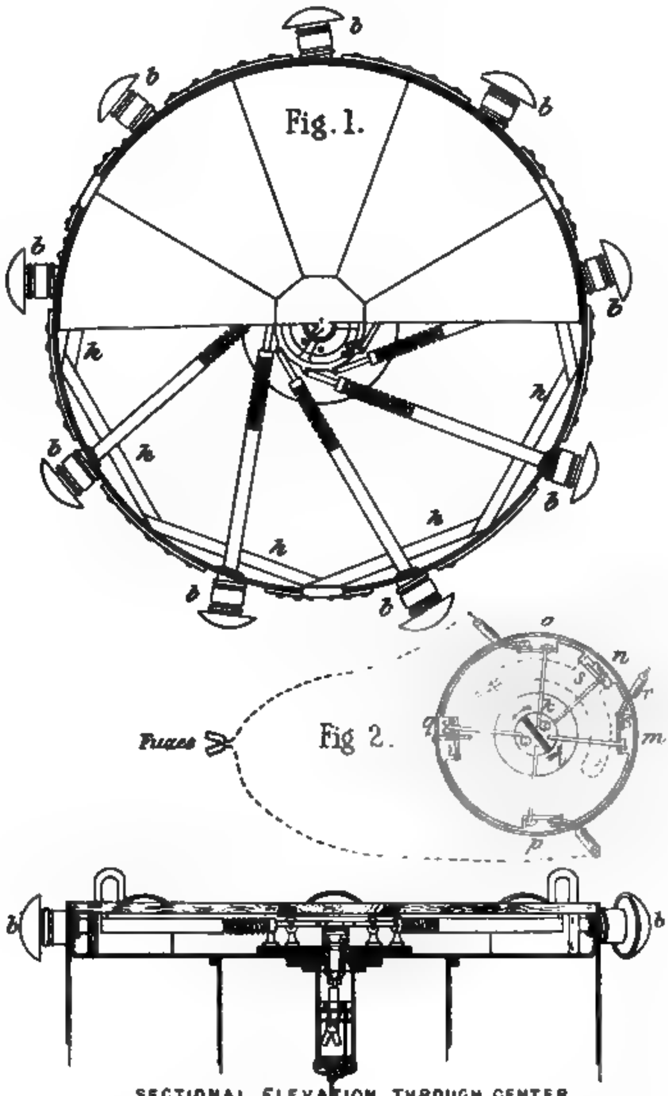
Strong pieces of wood *h*, *h*, *h*, round the circuit closer, keep the buffers and their attached arms in the proper direction, and give rigidity to the part of the iron cylinder through which they pass.

Mode of action of apparatus.

The brass ratchet wheel *g* being put in motion, carries round with it a central arrangement *i* the lower part, (that nearest the fuze), of which is shewn in detail in *Plate* LXIX., *Fig.* 2. This central portion consists of a brass cylinder *k* divided into two portions, insulated from each other by a division of ebonite *l*, shewn in black; one side of this cylinder is fitted with three arms of brass, *m*, *n*, and *o*, and the other with two arms, *p* and *q*, all of which are carefully insulated from each other by indian-rubber.

PLATE LXIX.

AUSTRIAN CIRCUIT CLOSER.



SECTIONAL ELEVATION, THROUGH CENTER

Lithographed at the S M E Chatham. B Butler, Corp^l R.E.

The arm *m* is close to, but insulated from a metal plate *r*, which latter is permanently connected with the conducting wire from the battery, and thus in its state of rest remains electrically charged. Beyond the arm *n* is a small spring *s*, permanently connected with the earth, and in such a position that when the central portion is moved round, this spring *s* comes in contact with the arm *n* and the plate *r* with the arm *m* simultaneously, and the circuit is completed through earth to the battery, without, however, passing through the fuze.

Referring again to *Plate* LXIX., *Fig.* 2, the arms *o* and *p*, on opposite sides of the brass cylinder and consequently insulated from each other, are connected with the fuze or fuzes, two being generally used, and the arm *q* is permanently connected with the earth.

We left the current passing from the battery, through the arm *m*, by the brass cylinder to the arm *n*, and, by the spring *s*, then in contact therewith, to earth, and completing the circuit; but by a still further pressure of the vessel on the buffer, the arm *h* is pushed beyond the spring, and contact therewith, and, consequently, circuit by earth to the battery, is broken, while the contact of the arm *m*, and plate *r*, is still retained, and the current is passed by the arm *o*, through the fuze to the arm *p*, and thence to earth, through the arm *q*, completing the circuit through, and firing the fuze.

The action of the spring, in breaking the circuit, has the effect of intensifying the current, (by means of an intensity coil in connection with the firing battery), to its utmost extent, and, at the moment when this intensity is highest, passing it through the fuze.

To render a channel safe for a friendly vessel.

Should a friendly vessel be approaching a line of mines arranged on this system, it would only be necessary to detach the firing battery, by removing the connecting plug, to render her passage perfectly safe. Should she make contact with any of the mines in her course, the ratchet wheel *g*, *Plate* LXIX., *Fig.* 1, would be pushed round, the spring, *s*, would make and break contact, as before described, but no current would be circulated; and on the vessel leaving the mine the ratchet wheel would be drawn back to its original position, by means of a small spring in connection with it, and be ready again to act when required. The arrangement for closing the circuit, is made sufficiently strong to prevent chance of injury from contact with a friendly vessel.

Fuze only in circuit at the moment of firing mine.

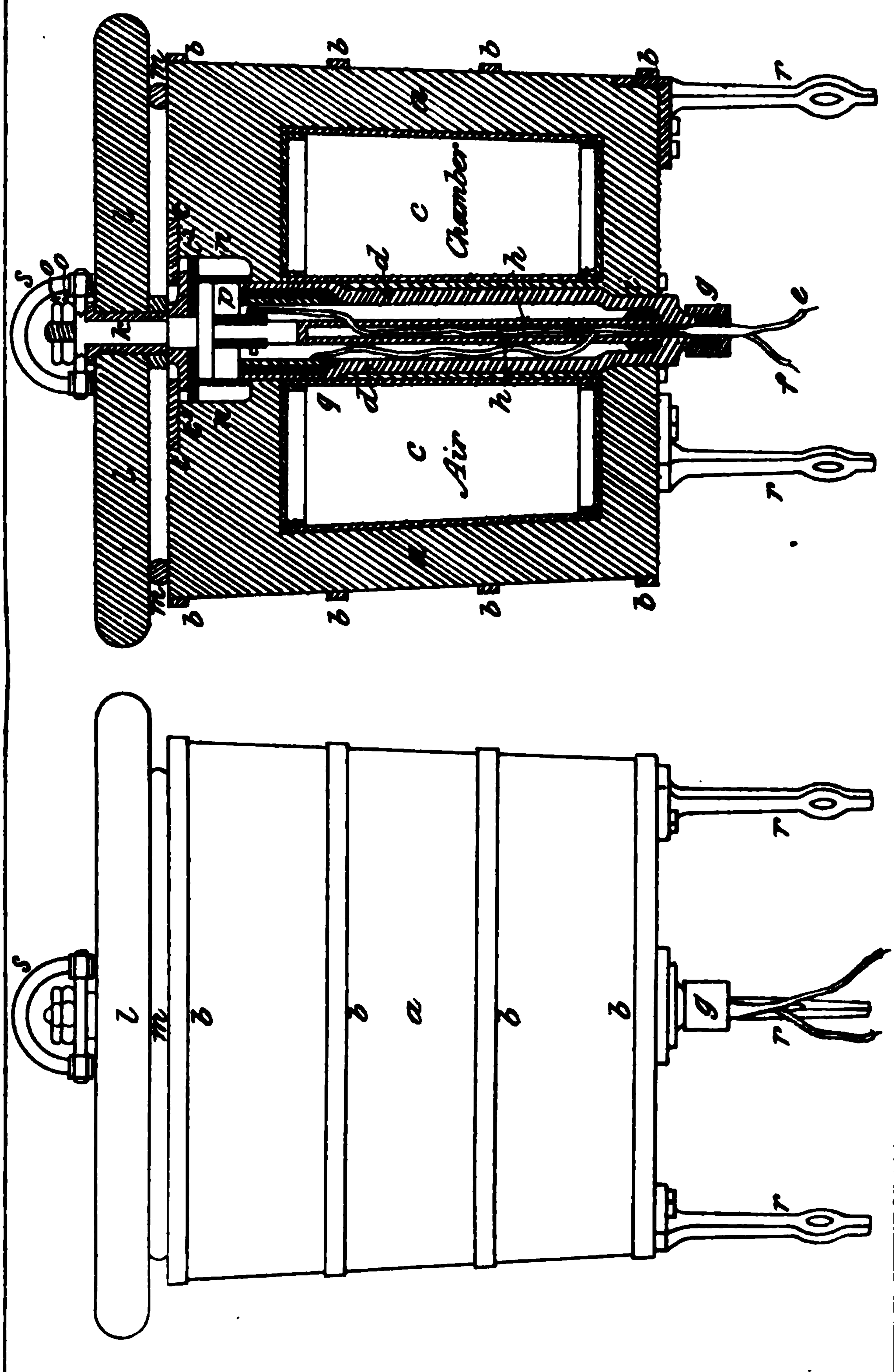
It will be observed that, in the Austrian system, the fuze is only put into the electrical circuit at the moment when it becomes necessary to fire it. This arrangement was considered necessary, to obviate the chance of the accidental ignition of a charge from induction, caused by atmospheric electricity. According to Baron Von Ebner, accidents of this nature have occurred to mines used by him. This mode of cutting the fuze

out of circuit till the moment of ignition, guards most effectually against such an occurrence, but, at the same time, it renders it impossible to fire the charge at will, and the ignition of the mine is thus reduced to that single condition in which the action of the circuit closer, by the contact of a vessel, is essential.

Abel's circuit closer.

Another form of circuit closer, designed by F. Abel, Esq., F.R.S., Chemist to the War Department, is shewn in section and elevation in *Plate* LXX. It consists of a strong wooden case *a*, bound with four iron bands *b*, *b*, *b*, *b*, buoyancy being given to it by means of an air-tight chamber *c*. Within the apparatus is a brass tube *d*, into the lower extremity of which a pair of insulated wires *e* and *f*, are introduced, by means of a joint *g*, enclosed in a stuffing box. This latter is rendered water-tight by a ring of indian-rubber, shewn in black in section, compressed against the insulation of the conducting wires, by the action of a screw working on the extremity of the brass tube *d*. In order to render this joint thoroughly water-tight, the insulation of the two wires *e* and *f* is, at this point, welded into one, and made into an elongated, oval form, thicker than the original insulation, by the addition of layers of Chatterton's compound and gutta percha in a plastic state. In thus welding the insulation, care must be taken to prevent the two conducting wires from being accidentally pressed into contact, while the gutta percha is softened by the heat necessarily applied. Within the brass tube *d*, is another tube of brass or iron *h*, extending vertically through the whole apparatus, and working on an universal joint *i*, at its lower extremity. The upper portion of this tube is rigidly connected with a metal bar *k*, which latter is firmly attached to a strong teak top *l*, supported on the wooden case *a*, and separated from it, by a vulcanised indian-rubber ring *m*. It is thus easily seen how any blow on the top would be transmitted to the metal cylinder *h*. The interior of the brass cylinder *d*, is kept water-tight by means of a vulcanized indian-rubber collar *n*, shewn in black in section, connecting it with a ring projecting from the metal bar *k*. A couple of metal screws *o*, *o*, are made to fit on a screw tapped on to the upper portion of the metal bar *k*, and, by means of a spanner, these may be screwed down so as firmly to connect the top of the arrangement with the wooden top *l*. One of the insulated conducting wires *e*, having been carried in through the metal tube *h*, is soldered on to a copper ring *p*, encircling the bar *k*, but insulated therefrom. The insulated conducting wire *f* is passed through a hole in the tube *h*, and its bared extremity is attached to a binding screw *q*, in connection with an insulated brass band, let into a broad ebonite ring, which passes completely round a hollow, in the brass tube, made to receive it. To the base of the apparatus, feet *r*, *r*, *r* are attached, on which it may stand in such a way as to keep the projecting piece *g* clear of the ground. Rings are

ABEL'S CIRCUIT CLOSER.



Lithographed at the S.M.E., Chatham.

B. Butler, Corp.l R.E.

formed in these feet for the attachment of the mooring chains. A ring *s* is attached to the upper portion of the apparatus, to facilitate manipulating and moving the circuit closer. A metal ring *t*, is let into the opening of the upper portion of the case *a* to take the weight of the outer case, when the circuit closer is lifted by the ring *s*. A thick ring *t'* of vulcanized indian-rubber keeps the whole combination rigid, and, by its resistance, dependent on its thickness, regulates the force which must be used to set the apparatus in action.

Mode of using the apparatus.

This circuit closer is designed for use, so that the fuze may either be kept entirely out of the circuit till the moment when it is required to be fired, as in the Austrian system, or it may be employed in the ordinary manner, with the fuze in circuit as usual. In the latter case only one wire need be employed, and this would be connected with the copper ring *p*; the insulated brass band is not then required, and the space allotted to it must be filled by metal. This would simplify the construction of the instrument.

Connections with the fuze out of circuit till the moment of ignition.

For the former combination, the electric cable from the firing battery is connected with the insulated wire *e*, the other pole of the battery being to earth, the wire *f* being attached, through an insulated conductor, to one pole of the fuze, and a metallic connection being arranged from the other pole of the fuze to earth. In order to fire the fuze it is easily seen that it is only necessary to bridge over the space between the copper ring *p*, to which the wire *e* is connected, and the brass ring *q*, attached to the wire *f*. This would be done by a vessel striking the top *l* of the apparatus in any direction, which being pressed on one side would carry with it the bar *k*, and, by the action of the universal joint *i*, bring some part of the copper ring *p*, in contact with the brass band *q*, thus completing the electrical circuit. In this combination, it is easily seen, how the fuze is only introduced into the circuit at the moment when it is required to be fired.

Connections with the fuze in circuit as usual.

When it is desired to arrange the fuze in connection with this circuit closer in the ordinary manner, the combination is as follows:—one pole of the firing battery being to earth, the other is connected, through the electric cable, with one pole of the fuze, the other pole of the fuze being placed in metallic connection with the insulated wire *e*, while the insulated wire *f* is put to earth by being connected with the metallic portion of the case *a*. In this combination it is easily seen that, in order to fire the fuze, it is only necessary to bridge over the space between the two brass rings *p* and *q*, which would be done, as already described, by the action of a vessel striking the top of the apparatus.

Advantages and defects of combina-

When the fuze is entirely out of the circuit till the moment of ignition, it cannot be fired at will, and cannot be tested except when a return wire is used; it is, however, manifestly

tions, with fuze permanently in or out of circuit

very safe from accidental ignition. On the other hand, when the fuze is arranged between the firing battery and the circuit closer, any considerable fault in the insulation, between the fuze and the circuit closer, would be very likely to cause an accidental explosion.

To render a channel safe for a friendly vessel.

In order to render a channel safe for a friendly vessel, it would only be necessary, in either of these combinations, to detach the firing battery, in which case, should a circuit closer be struck, it would re-establish itself in its former condition by virtue of the action of the flat indian-rubber ring t' and the collar, n, and be ready to act effectively as before.

Efficiency of Abel's circuit closer.

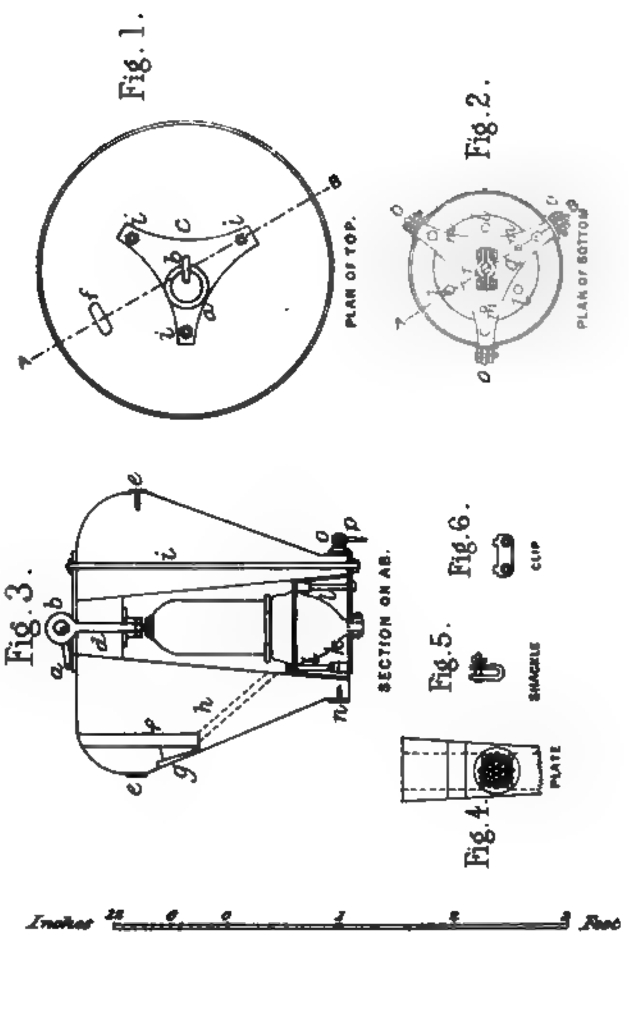
From experiments carried on at Chatham with several circuit closers of the form described, it has been proved that they are very efficient in action, and that the strong, external, wooden case possesses sufficient resisting power to enable them to stand a good deal of knocking about and rough usage, without damage to the internal circuit closing arrangements. This power to resist heavy blows is essential to the efficiency of any form of circuit closer, as, when in position in a channel through which there is much traffic, they are always liable to be struck with considerable force by blades of screws, floats of paddles, and other hard and sharp bodies. It would be an improvement if the stuffing box g were arranged to be flush with, or at least to extend as little as possible below, the bottom of the apparatus. Its projection, as shewn in *Plate* LXX., renders it very liable to injury from a side blow. This improvement might no doubt be very easily effected, but the same object has been attained, in the most recent pattern of this circuit closer, by fixing a stout metal cap over this stuffing box, the conducting cable being brought out through an opening therein.

Mathieson's inertia circuit closer and breaker.

Another form of circuit closer has been designed by Qr.-Mr. Sergt. Mathieson, R.E. This apparatus, which has been very much improved since it was first proposed, has been subjected to a long series of experiments, and its advantages compared carefully with Abel's circuit closer. After much consideration, it has finally been adopted for service, in the form shewn in *Plates* LXXI. and LXXII.

It consists of two parts, an internal dome, of soft gun metal, attached, so as to be water-tight, to a metal base, and covering the circuit closing apparatus, and a wooden jacket, within which the copper dome is firmly secured. This latter is intended to provide a considerable part of the floatation, and to save the more delicate internal arrangements from damage, when struck by passing vessels. To this latter are attached the mooring chains, used to connect the circuit closer with the charge. *Plate* LXXI., shews the general arrangement of this form of apparatus, with its wooden jacket, &c., complete. *Fig.* 1 shews a plan of the top and *Fig.* 2 a plan of the bottom; *Fig.* 3 shews

MATHIESON'S CIRCUIT CLOSER, AND BREAKER.



Lithographed at the S. M. E., Chatham. *B. Butler, Corpl R. E.*

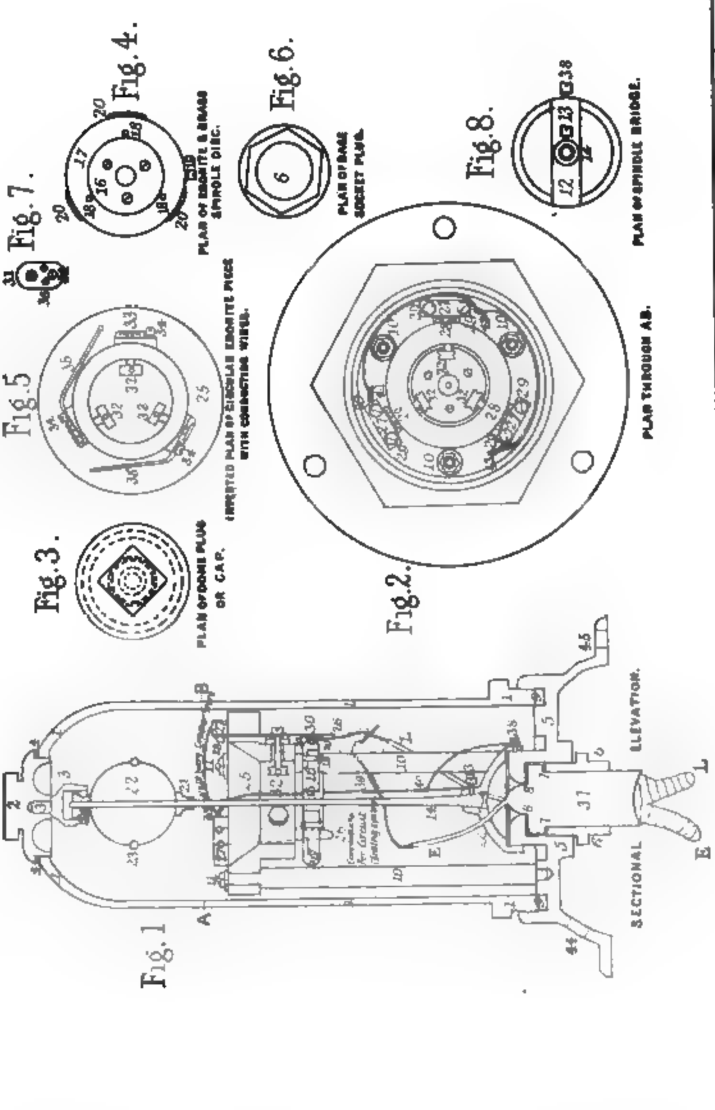
a section, on the line A B, through the centre of the whole. *a* is a ring on the top, by which the apparatus may be suspended, when required to be moved: this ring is attached by means of an eye bolt *b*. *c* is a triangular top plate of iron, connected, by means of wrought iron bolts and nuts, *i*, *i*, *i*, to a corresponding triangular plate *q* on the bottom: these plates, together with two hoops, *e* and *n*, passing completely round the outside of the wooden jacket, the former at its swell and the latter at its base, hold the whole apparatus firmly together: *d* is the top plug of wood, through which the eye-bolt *b* passes, and to which it is secured by a nut and washer, to strengthen it for suspending the circuit closer: *f* is a chamber in the woodwork of the jacket, in which the earth plate is deposited when the apparatus is connected up for use: *g* is a perforated metal plate, through which free access is given for the water to reach the earth plate; this is shown in elevation in *Fig.* 4: *h* is a hole, bored through the thickness of the wooden jacket, by which the insulated wire connecting the earth plate, deposited in the chamber *f*, is conducted to its attachment with one wire of the ebonite base plug: *k* is the wooden base plate, through which three bolts *l*, *l*, *l* pass, by which it is firmly secured to the metal base: the wooden base plate is attached to the bottom iron triangular plate *q* by three riveted bolts *m*, *m*, *m*. A hollow is provided in the wooden base plate, for the reception of the insulated joints of the terminals of the ebonite base plug with the earth plate connections, and with the electric cable, connecting the charge, and to protect these from injury. *o*, *o*, *o* are three lugs, at the outer extremities of the iron triangular bottom plate, for the reception of three shackles, *p*, *p*, *p*, for the attachment of the mooring chains: one of these shackles is shown in elevation in *Fig.* 5. *r* is a clip, attached to the outside of the triangular plate of the base plate, by which the electric cable, connecting the charge with the circuit closer, is gripped, in passing into the latter: *Fig.* 6 shews an elevation of the clip: it consists of two parts, one fixed on the iron triangular plate and the other moveable; the two are held together by means of screw bolts and nuts, which are used in tightening the apparatus up over the electric cable. For mooring purposes, three $\frac{3}{8}$-inch attachment chains are provided, one connected to each of the shackles *p*, *p*, *p*: they are attached at the bottom to a $\frac{1}{2}$-inch round iron ring, $2\frac{1}{2}$ inches in diameter, to which the mooring cable, connecting the charge, may be fastened by means of a shackle.

Details of apparatus within the dome.

Plate LXXII. shews the details of the circuit closing apparatus within the dome. *Fig.* 1 is a vertical section through the centre, and *Fig.* 2, a plan, looking downwards, on the level A B: the references are indicated by figures. (1) is a soft gun metal dome, attached to a metal base (5), into which it is firmly screwed, its foot resting on a gutta percha washer, (9), so as to exclude water.

(2) is a cap, attached by a screw to the top of the dome, and made water-tight by means of a leather washer (4): for work this washer should be well saturated with red lead. A plan of the cap (2) is shewn in *Fig.* 3. (3) is a guard cap, screwed into the cap (2) of the dome: this is intended to keep the spindle steady during transport, and would be removed when the apparatus is prepared for work; (37) is the ebonite base plug, through which a pair of wires, E and L each carefully insulated, pass, for the connection of the circuits. (6) is a union with screw, by which the ebonite base plug is attached to the base plate: (7) is a brass collar, between this screw and the base plug, and (8) a leather washer between the base plug and the metal base, by which water is excluded: for work, this latter should be well saturated with red lead. A plan of this part of the apparatus is shewn in *Fig.* 6. (10, 10, 10) are brass columns, supporting a circular ebonite piece, (25), and attached thereto by three nuts and washers, (11, 11, 11). (12) is a metal bridge, connected to the base (5) by a screw, and supporting the steel spindle (14): a set screw, (38), fixes the bridge firmly, after it has been screwed up, to the metal base, and a similar screw, (13), performs the same office for the spindle, in connection with the bridge. A plan of the metal bridge, &c. is shewn in *Fig.* 7. The spindle carries a leaden ball, (22), at its upper extremity, supported on a rest, (21), below, and secured at the top by a screw nut, (24). The outer circumference of the leaden ball is provided with an indian-rubber ring, (23), so that in the event of its coming violently in contact with the metal dome, when set in action by a heavy blow from a passing vessel, no damage may be done to the apparatus. (15) is a brass disc, attached to the spindle, carrying an ebonite disc, (16), attached to it by means of screws: (17) is a brass contact ring, also fixed to the ebonite disc (16), by means of screws, (18): this ring, (17), the lower part of which, with its connections, is shewn in plan in *Fig.* 4, is provided with a screw, (19), for the attachment of the electrical connections, and with platinised projections, (20, 20, 20), by which contact is made through any one of the corresponding platinised contacts of the springs, (30, 30, 30). The contact ring, (17), in this arrangement, is completely insulated from the spindle and brass disc, (15). Three contact springs, (26), are attached to the circular ebonite piece, (25), by means of screws, (28), fixing them to blocks, (27), which latter are attached to the ebonite piece by means of screws, (29): a plan of the bottom of this part of the apparatus is shewn in *Fig.* 5. (31), are the connecting pieces for the springs, on the lower part of the ebonite piece, shewn also in *Fig.* 7. (32), are the contact screws of the connecting pieces; the points, (33), of these screws, as well as their bearings on the springs, are platinised, to ensure good metallic contact. (34), is the connecting screw of each contact piece, by means of which the connecting wires, (35), are attached thereto: (36) are brass screws, for fixing

MATHIESON'S CIRCUIT CLOSER, AND BREAKER.



Lithographed at the S. M. E., Chatham. *B. Butler, Corpl. R. E.*

these contact screws in their places. The connecting wires, (35), pass through to the top of the ebonite piece, and are attached to the block at the top of the spring next in succession to that to which they are fixed below. The resistance coil, of 1000 ohms, used for testing purposes, is attached to the line L terminal of the ebonite base plug, by means of a joint, the line L terminal being also placed in direct metallic connection with the screw, (19), on the outer circumference of the contact ring. (39) is a joint, connecting the other terminal of the resistance coil of 1000 ohms to the earth E terminal of the ebonite base plug. The 1000 ohms coil is itself very firmly lashed to one of the brass supporting pillars, to prevent any motion during transport or in use, as the slightest movement has been found to be very injurious to the wire connections. This connection with the 1000 ohms coil completes the arrangements for testing purposes. For signalling, a bare copper wire, of No. 16 B.W.G., is arranged to connect the top of the last contact spring with the set screw, (13), while a second piece of wire, of similar gauge, is attached to it by a joint, (40), it is then passed round one of the supporting pillars and connected to the set screw, (38); where it comes in contact with the brass pillar it should be firmly bound to it, as a precautionary measure, to secure a good earth connection in the event of that through either of the set screws failing. (41, 42, and 43), are joints, connecting the wires from the top of each vertical spring to the contact screw of its neighbour. This completes the connections for the signalling circuit, the earth for this latter being formed by the body of the instrument. The connections here enumerated are somewhat more detailed than those given in page 155, which are not sufficiently explicit for practice. (44), is a hole left in the metal base, for the passage of the insulated wire connecting the earth plate to the earth E terminal of the ebonite base plug. (45), is one of the three holes provided for the passage of the bolts, by which the wooden base piece is connected to the metal base.

Mode of action of apparatus.

The mode in which the testing and signalling currents circulate, when the apparatus is connected as above described, is easily seen by a reference to *Plate* LXXII. For testing purposes the current arrives by the line L terminal of the ebonite base plug, and passes thence, through the 1000 ohms coil, to the earth E terminal of the same, and on to the zinc earth plate, deposited in the recess in the circuit closer jacket. When the apparatus is struck by a passing ship, the weight of the leaden ball, (22), causes the steel rod, (14), to be deflected, and brings the contact ring, (17), in collision with one of the springs, (26), at the platinised plate, (30). When in this position, the signalling current passes from the line L terminal of the ebonite base plug, (avoiding the resistance of the 1000 ohms coil), direct from the contact ring to the spring struck, thence to the top of the spring, and,

by the wire connections, down to the set screws, (13) and (38), and the mass of metal of the body of the instrument, which, being immersed in the water, forms an excellent earth connection. It is easily understood, that as long as this signalling current was obliged to pass through the high electrical resistance of the 1000 ohms coil, the presence of that resistance prevented it acting with such power, on the coils of the electro-magnet of the shutter apparatus, as to produce sufficient magnetic force to attract the armature and drop the shutter, yet, as soon as that resistance of 1000 ohms was eliminated and the current passed direct to earth, the armature would be attracted, the shutter released, the firing battery thrown into circuit, and the mine fired.

Effect of springs in prolonging contact.

The effect, when the circuit closer is struck, is to produce a series of vibrations, due to the oscillation of the steel rod, entailing a series of contacts: and the action of the springs causes a slight prolongation of those contacts, which latter is somewhat important when a platinum wire fuze is used; the exceedingly small duration produced, giving time for the effectual heating of the thin platinum wire forming the bridge of that fuze: this slight duration, has been found to be necessary, to produce the desired effect in the case of the platinum wire fuze. This circuit closer is, however, equally applicable for use with any form of high tension fuze, which may be employed for submarine mining service.

Protection afforded by wooden jacket.

The external wooden jacket of this apparatus, is a very efficient protection to the more delicate portion of the instrument, which, without it, would be very liable to injury if exposed to blows from the screws or paddles of passing steam vessels, or from other hard and sharp substances with which it might come in contact. Circuit closers of this form have been very severely tried for several years, in the Medway and at the Nore, and have been subjected to very hard usage and severe blows without any material injury to their working powers. The pear-shaped form of the wooden jacket, tends to make the apparatus float in an upright position in the water, and by increasing its diameter, gives it a better chance of being hit by passing vessels.

Bessemer steel jacket proposed by Col. Milward, C.B., R.A.

Experiments are now being made with a circuit closer provided with a Bessemer steel jacket, on a plan suggested by Colonel Milward, C.B., R.A., Superintendent of the Royal Laboratory at Woolwich. The object of using steel, is to obviate the chance of the jacket becoming water-logged, which occurs, to a certain extent, with a wooden jacket after long immersion, as well as to produce an article better adapted for storage purposes, that is to say, composed of a less perishable material. The jacket suggested is composed of Bessemer steel, and is furnished with a strong wooden disc at the top, to take the heaviest part of the blows to which it may be subjected. The result of the experi-

ments, to which this form of jacket has been subjected, is very satisfactory: in reporting on it, the Torpedo Committee have recommended that it be provided with internal compartments, so that even if stove in, it may still retain a sufficient amount of floating power: in addition to this, they have suggested a few minor alterations in details and recommended a further trial. The circuit closer, with wooden jacket, complete with internal mechanism and attachment chains, as made in the Royal Arsenal at Woolwich, weighs about 330lbs., and possesses a net buoyancy, when perfectly dry, of from 180lbs. to 200lbs. Several of these have been tried, by a continuous immersion of upwards of nine months at the Nore, and during this period have lost some 50lbs. or 60lbs. of buoyancy, in consequence of the infiltration of water. This loss of buoyancy does not, however, materially affect their working powers, and they still remain as serviceable as ever. The Bessemer steel jacket has been constructed with the same amount of buoyancy as the wooden jacket when perfectly dry, and it does not, of course, deteriorate in the same manner, by becoming water-logged during immersion. The wooden jackets have proved themselves so efficient as regards floatation, that the substitution of steel on this account would scarcely seem necessary, but as regards storage qualifications, there can be no doubt as to the superiority of the metal: even with the greatest care, wood is always liable to rot and decay.

Floatation of circuit closer, complete.

Construction of wooden jacket.

The wooden jacket for the circuit closer is made in a very similar manner to the jacket of the 100lbs. electro-contact, gun-cotton mine, described at page 53. It is composed of yellow pine, formed in segments, connected together by marine glue, subjected to a hydraulic pressure of 2,800lbs. on the square inch, to ensure the joints fitting closely, and turned all over. It is bound together, at the swell and bottom, by wrought iron truss hoops, and the chamber *f*, *Fig.* 1, *Plate* LXXI., to contain the earth plate, is formed in one of the segments. When put in store, the woodwork should not be painted or tarred; when required for use, however, the whole external surface of the woodwork should be coated with a mixture of pitch and tar well burnt in.

To connect the apparatus as a circuit breaker.

Mathieson's circuit closer has been designed to act also as a circuit breaker: that is to say, to give a signal by the cessation of a passing current, in contradistinction to the closing of the circuit on the system above described. In order to fit the instrument as a circuit breaker, it is only necessary to alter the mode of connection, by carrying the line L terminal of the ebonite base plug to the first screw (34), *Plate* LXXII., *Fig.* 3, on the lower part of the ebonite ring carrying the springs and their connections: the arrangement of connections between the springs, by wires, (35), attached to them above and below the ebonite ring, would be the same as before, while the earth E

terminal of the ebonite base piece, is attached to the upper part of the last spring by the screw (29). In this combination the 1000 ohms coil is dispensed with, as well as the wire connections between the top of the spring and the set screws (13) and (38): the bare wire connections, between (41) and (42), and between (42) and (43), *Fig.* 2, *Plate* LXXII., on the upper part of the ebonite ring, must also be removed. It is necessary to see that the contacts, between the ends of the adjusting screws, (32, 32, 32), and the inside faces of the vertical springs, are very clean, as the current must circulate through the whole of them, in passing from line to earth, before the apparatus is set in action by a blow from a passing ship.

Mode of action.

The mode in which the instrument works in this combination is very simple. As long as it remains at rest, the current passes from the line wire to the screw, (34), thence through the system of springs to the last screw, (29), on the top of the ebonite ring, thence down to the earth E terminal of the base plug, and on to the earth plate in connection therewith. Should the circuit breaker receive a blow, the steel rod (14) would be deflected as before, the disc (16) would impinge on one of the vertical springs and force it, for an instant, away from its contact with the corresponding screw, (32), which would, for the time, destroy the continuity of the circuit. In the circuit breaking system, the shutter of the shutter signalling apparatus is held up by the armature when attracted to the electro-magnet, it would therefore remain so held up as long as the current is in circulation, but the moment a break occurred in the circuit, the current would cease, the armature would no longer be held over by the electro-magnet and would fly back and release the shutter, which would fall and throw the firing battery into circuit as before. The break in the continuity of the circuit is only momentary, and directly the steel rod moves back, in vibratiug, the circuit is re-established, giving a passage for the current of the firing battery, which would thus fire the mine. The circuit breaker system was specially designed for use with the platinum wire fuze.

Circuit closer of 100lbs. electro-contact mine.

The circuit closer of the 100lbs. electro-contact mine is shewn, in section, in *Plate* IV., and is very similar in construction to that here described.

The only difference is that the circular ebonite piece (25), *Plate* LXXII, *Fig.* 1, is replaced by a similarly shaped piece formed entirely of brass, and which is in metallic connection, through the pillars (10, 10, 10), with the mass of metal of the apparatus which forms the earth plate. The connections of the fuzes may be seen by reference to *Plate* IV, page 52. The insulated wire of the ebonite base plug, is connected to one pole of a platinum wire fuze, the two fuzes are themselves arranged in simple continuous circuit, and from the opposite pole of the second fuze, an insulated wire is carried to the outer metal rim

of the disc of the spindle. It is easily understood that, as long as the circuit closer remains stationary and undisturbed, a break, due to the ebonite insulation between the spindle and the outer metal rim of the disc, will remain in the circuit: but the moment the apparatus is struck and the spindle deflected, the outer metal disc will make contact with one of the springs, completing the electrical circuit, through the circular metal portion and pillars of the instrument to earth.

Adjustment of sensitiveness of instrument.

In order to regulate the sensitiveness of the apparatus, adjusting screws, (32), opposite each spring, *Fig.* 1, *Plate* LXXII. are provided. These screws press against the springs, and by them the intervals between the disc (16) of the steel rod and the springs may be increased or diminished at pleasure. To adjust the instrument, it is laid on its side, with the dome removed and resting on a wooden seat, and a weight of 600 grains is suspended from the milled-headed screw (24) at the end of the rod. This weight of 600 grains has been arbitrarily assumed, having been found in practice to answer the purpose, in regulating the sensitiveness of the circuit closers, which have been in use for our experiments at the Nore. The distance of each spring is regulated in succession, by means of the screw (32) in connection with it, so that the weight just causes the steel rod to yield sufficiently to make contact, as indicated on a galvanometer which, with a small battery, is kept in circuit. As the temper of all the steel rods may not be exactly the same, the apparatus should subsequently be further tested, by rocking it with a gentle and uniform motion, and turning it completely over on its side, keeping the small battery and galvanometer still in circuit: should the adjustment be correct, no contact should be made under this treatment, but the smallest movement, in the shape of a jerk, should close the circuit and deflect the galvanometer. The object of this adjustment is so to regulate the apparatus, that it may remain undisturbed when subjected to the rocking action of the sea, while at the same time, it should act with certainty when struck by a comparatively light blow. With care, no difficulty has been experienced in regulating the apparatus so as to fulfil these conditions. No instance has occurred in which a circuit closer, which has been properly adjusted, has been set in action by the sea, even when subjected to very rough weather, while under experiment at the Nore, and yet, when struck by passing vessels, signals have been received with considerable certainty.

Contacts to be cleaned.

In connecting up a circuit closer or breaker, it is of the utmost importance that all the platinum contact points, on the several screws and springs, should be clean and bright, so that no resistance may be opposed to the passage of the current on account of dirt. These contact points are platinized to ensure this to the utmost extent.

Quarter-Master Sergeant Mathieson's original idea, on which

Pendulum circuit closer

the instrument above described is an improvement, was that of a weight arranged in the form of a pendulum. It was, however, too sensitive for actual practice; though excellent in still water, it was easily affected by a comparatively slight swell, and was consequently abandoned.

Pendulum circuit closer suggested by Lieut. R. F. Moore, R.E.

Lieut. R. F. Moore, R.E., has suggested a circuit closer on the pendulum principle. It is simply a common bell, the clapper of which is insulated from the body, and the circuit is closed by bringing the former in metallic contact with the latter. This apparatus has not been sufficiently tried; being similar in principle to Mathieson's pendulum, it is to be feared that it would fail from similar causes. It would no doubt stand the regular and uniform swing produced by a sea, as Mathieson's did, for a considerable time, but the slightest deranging influence caused the latter to close the circuit, and it is difficult to understand how it could act in one case and not in the other.

Mc Evoy's circuit closer

Captain Mc Evoy, late of the Confederate Torpedo Service, now of the London Ordnance Works, Bear Lane, Southwark, has designed a circuit closer very similar in principle to Mathieson's. The general construction of this apparatus is given in *Plate* LXXIII. It consists of a brass tube *a* shewn in section in *Fig.* 1, into the head of which an insulated wire is passed, through a waterproof and insulated connection; this communicates with a priming chamber *b*, in which two fuzes *c c*, in direct circuit with the insulated wire, are placed. The priming charge, of powder or other explosive, is introduced into the chamber *b* through an opening in the side, closed by a screw cap. Beyond the priming chamber is a steel spindle or bar *d*, connected at its base with the insulated wire and fuzes, but insulated at this point from the external brass tube: to the extremity of this steel bar is attached a weight *e*. The chamber containing this steel bar and weight, is completely separate from the priming chamber *b*, and its outer extremity is closed by a screw cap and washer. A brass spiral strip *f*, is attached by one extremity to the brass tube, within the chamber at its extremity and immediately opposite to, though well apart from, and not in any way in contact with, the weight *e*: this passes round the top of the inside of the tube, making two or three convolutions, and is arranged to act as a spring. This completes the circuit closer proper.

Mode of action.

The mode in which this apparatus acts is very simple. As long as it is upright, the steel bar *d*, carrying the weight *e*, will remain vertical and clear of the brass spring *f*, but the slightest blow or jar deflects the steel bar, through the weight at its top, the latter comes in contact with the brass spring *f*, which, being in metallic connection with the brass tube *a*, closes the circuit through earth, if the other pole of the battery, attached to the insulated conductor and fuzes, be also connected to earth. The

Mc EVOY'S CIRCUIT CLOSER.

Fig. 1.

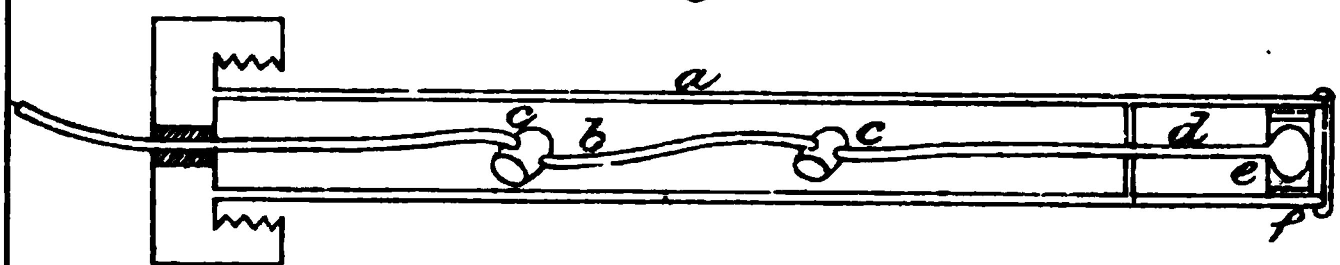


Fig. 2.

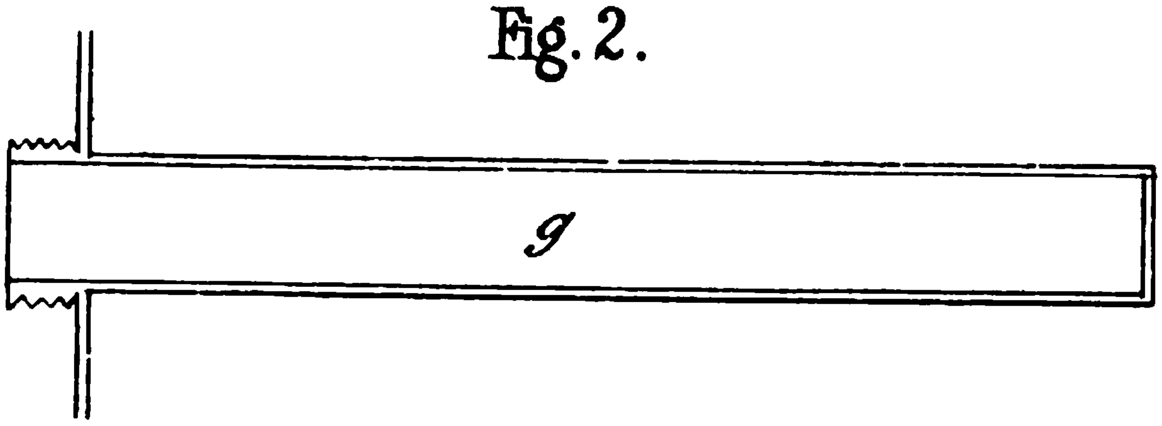
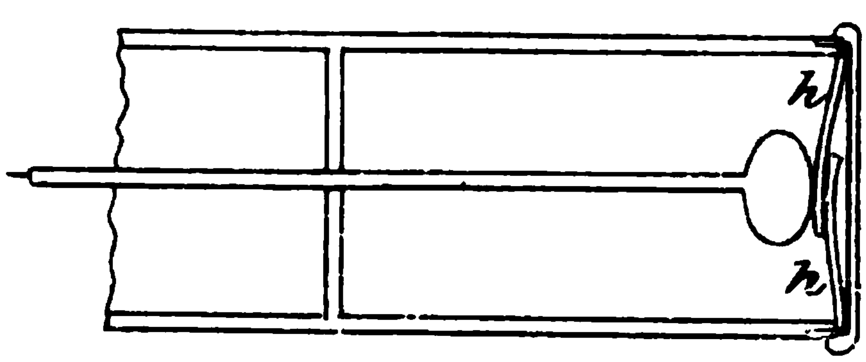


Fig. 3.



Lithographed at the S. M. E., Chatham. *B. Butler. Corpl. R. E.*

object of the spiral spring f is to prolong the contacts, when the spindle d is deflected. The regular motion, produced by the waves of the sea, does not seem to affect this apparatus: the whole, (spindle with weight and brass tube), swings together and the former is not brought in contact with the spring f: the slightest blow or jar, however, deflects the spindle immediately and produces the required result of closing the circuit.

Introduction of apparatus into a charge

Captain McEvoy proposes to carry the circuit closer separate from the charge, and only to insert it in the case when required for work. For this purpose he arranges a water-tight tube g, *Fig.* 2, projecting into the case to contain the charge, with a lip, on which a screw has been cut outside for the attachment of the circuit closer. The outer extremity of the brass tube a, *Fig.* 1, of the circuit closer is constructed of corresponding shape, to screw on over this lip, and the whole is made water-tight, by means of a washer placed in the hollow of this latter, on which pressure is brought to bear through the screw. In the apparatus as at present made, it is difficult to get at the fuzes in the interior of the priming chamber b, the only opening being through the loading hole: Captain McEvoy proposes, however, to obviate this by re-arranging the construction of the apparatus, so that it may be easily opened at this point to give facilities for examination. The simplicity of construction and compact shape of this form of circuit closer are very advantageous: a few experiments tried with it, seem to indicate that it is not so well adapted, for the system of submarine mines adopted by the Torpedo Committee, as Mathieson's, it has not, therefore, been thought of as a substitute for the latter. The contacts produced by its action are slightly less prolonged than those obtained with Mathieson's instrument.

Circuit breaking arrangement

Captain McEvoy has arranged this apparatus for use as a circuit breaker, by the device shewn in *Fig.* 3. For this purpose, he has placed two brass springs h, h, in metallic contact with the end of the metal tube, so that they may press upon the top of the ball, when the latter is stationary and remains vertically in the centre of the tube. Directly the spindle is deflected, the contact between these springs and the top of the ball is, for an instant, broken, which thus interrupts the circuit.

Mathieson's dual-electric circuit closing arrangement

Another form of circuit closer, suggested by Quarter-Master Sergeant Mathieson, R.E., may be described as follows:—It consists of a glass vessel containing, and at the same time insulating, the earth connection. This glass vessel is so arranged that a ship would come in contact with and break it, when the circuit would be completed, by the earth plate through the water, and the charge fired.

He proposes to moor his mines in pairs, at a depth of about 3 feet below the surface of the water, and to sustain them in that position by means of small surface floats, possessing just sufficient

buoyancy to keep them in position without being too conspicuous, as described in page 76. Though this arrangement has not been found to answer, in consequence of the reasons given in the description referred to, there is no reason why the mines themselves might not be floated up from sinkers on the bottom in the usual way, though they would not, under such circumstances, be effective at all times of tide. He proposes to connect each mine of the pair to a hermetically-sealed vessel, placed midway between them, by means of strong lines. He proposes to carry his electric cable from the firing battery on shore to a point on the bottom nearly midway between the pair of mines, continuing the electrical connection by branches thence to the fuze in each mine, and from each fuze to an earth plate enclosed within the glass vessel between them.

Mode of action.

A ship passing between a pair of such mines, would throw a strain on the lines connecting them with the glass vessel, the mines themselves would be drawn towards the ship's sides, the glass vessel would be broken, the earth plate contained in it would be brought in contact with the water, and the poles of the firing battery being connected respectively to the electric cable and to earth, the charge would be fired.

In such a combination, care must be taken to leave plenty of slack in the electric cables, so that the strain may not come on them, but on the lines connecting the glass vessel with the mines.

In the event of a vessel being observed to pass without exploding the mines, Qr.-Mr. Sergeant Mathieson proposes an alternative mode of firing, by the frictional electrical machine; by means of a switch pin the battery would be disconnected, and the frictional machine, with its condenser ready charged and earth connection made good, thrown into circuit. On the condenser being discharged, the small length of cable beyond the fuze would act, in conjunction with the surrounding water, as a Leyden jar, and the tension of the charge produced by this very powerful machine, combined with the inductive action set up between the metallic conductor, forming the inner, and the water, forming the outer coating of the Leyden jar, would be sufficient to fire such a fuze as No. 1, electric, Abel, or No. 5, detonator, electric, Abel, submarine. The platinum wire fuze could not be used in this combination.

Experiments to test power of firing by frictional machine with small length of

Experiments were tried at Chatham on the 18th of May, 1870, to test the power of the frictional machine to fire a charge by induction in this way. A cable, half a mile long, consisting of a strand of 7 No. 22 B.W.G. copper wires, insulated to $\frac{3}{16}$in. with Hooper's patent di-electric, was laid out on the ground and a fuze attached to the far end with 12 feet of electric cable beyond it, the latter immersed in water, but with its end

carefully insulated. Under these conditions, Abel's mining fuzes, (No. 1 fuze, electric, Abel), were fired with certainty, by a portable, ebonite, Austrian, frictional machine, not only when applied directly to the cable to which the fuze was attached, but by induction, when a charge was passed through half a mile of similar cable, laid parallel to it on the ground at a distance of 3 feet. A battery of 100 Daniell's cells failed to fire the fuze by induction, under either of the circumstances specified.

electric cable used as a Leyden jar.

This system possesses the disadvantage that, unless it was so arranged that the mines could be drawn down out of the way, the first vessel, friendly or otherwise, which passed through would break the glass vessel, and, probably, also the electric cables, connecting it with the mines. By simply detaching the firing battery no injury need occur to a friendly vessel; but even if the electrical connections remained in working order, the mines would be reduced to the condition of being capable of being fired at will only. Charges might be arranged to be hauled down, under certain circumstances, to allow friendly vessels to pass, but, as a rule, this would be a very difficult operation, and probably not applicable to the majority of cases. The power of the frictional machine to fire charges arranged in this way, is no doubt very great, but the danger of induction when using it must not be lost sight of,—see description in pages 121 and 206,—and its employment must therefore be limited to conditions in which this serious disadvantage may not be productive of unintended results.

Disadvantages of the system.

These are some of the most practical forms of circuit closer capable of application under various conditions, but no doubt others might be designed suitable for the purpose.

Most circuit closers are capable of being used, either in the same case as the charge, or detached from it and only connected by a suitable mooring line and electric cable. In the Austrian system, the circuit closer and charge are a part of the same case, and are so arranged that the charge will only explode when a vessel is in actual contact with it, or nearly so. The reason of this is, that the Austrian military authorities were of opinion that, to be effective, a charge must be fired in very close proximity to a vessel's hull. Having been designed for use in the tideless waters of the Adriatic, the combined charge and circuit closer could be easily moored, at a defined depth below the surface of the water, which cannot be done where there is a rise and fall of the tide.

Circuit closers may be combined with mines, or detached from them.

One advantage arising from a combination, in a single case, of the circuit closer and charge, is the additional inertia thus obtained, proportioned to the weight of the latter. The general tendency of any body, floating in water, on being struck by a ship, is to move easily on one side, and thus to lessen the force

of the blow; the greater inertia of the combined charge and circuit closer, is therefore in favor of the combined action of the circuit closing apparatus.

Detached circuit closer proposed by Floating Obstruction Committee.

The Floating Obstruction Committee have proposed a detached circuit closer; this decision has been, in a great measure, governed by the fact of the great rise and fall of the tide, in the estuaries and harbours of Great Britain and Ireland. They trust to the radius of the destructive effect, due to the explosion of any given charge, extending to a certain distance from it. What this distance is has yet to be definitely determined, but experiments prove that it is not limited to actual contact with the charge, though it diminishes rapidly in proportion to the increased cushion of water intervening, as the distance from the side of a vessel increases. There is no doubt, that in a tidal harbour or estuary a detached circuit closer presents many advantages, one of which is that the position of the actual charge may be arranged, so as to suit the ever varying depth of water over it, with greater facility, when the circuit closer is detached from it. It is probable that neither detached circuit closers nor those permanently combined with the charge can be universally adopted; measures have therefore been taken by the Torpedo Committee, to design different forms of case for each combination. Mathieson's circuit closer is readily adaptable to either.

Enemy would endeavour to render mines ineffective.

The first object of an enemy in attacking a harbour defended by submarine mines would be, if possible, to explode those mines, and thus render the ground in his front safe; or, failing to do this, to get hold of and carry off the circuit closers, and, if possible, to dispose of the electric cables in connection with them in such a way as to render the charges unexplodable; and as it is not desirable to throw away large charges upon boats and small craft, such as would be employed in the duty of searching for mines, means must be taken to retain the charges intact and effective, even should the circuit closers be carried away.

Power of firing mine should be retained, if possible, after removal of circuit closer

Should an enemy simply break away a circuit closer, and allow the end of the electric cable to fall off, there would, of course, be no difficulty in still firing at will, if the fuze were arranged in circuit as in *Plate* LXXIV., *Fig.* 1. Supposing the circuit closer *n* removed, the fractured conducting cable would still, in most cases, be sufficient to pass the current to earth on the circuit of the battery *c z* being completed, and this operation could easily be performed within the testing room. Under these circumstances the mine would remain as effective as ever, provided the means of identifying the position of a vessel existed. Supposing, however, that an enemy, knowing the arrangements prepared for his reception, were, before casting off the broken end of the conductor, after detaching the circuit

CONNECTIONS OF CIRCUIT CLOSER &c.

Fig.1.

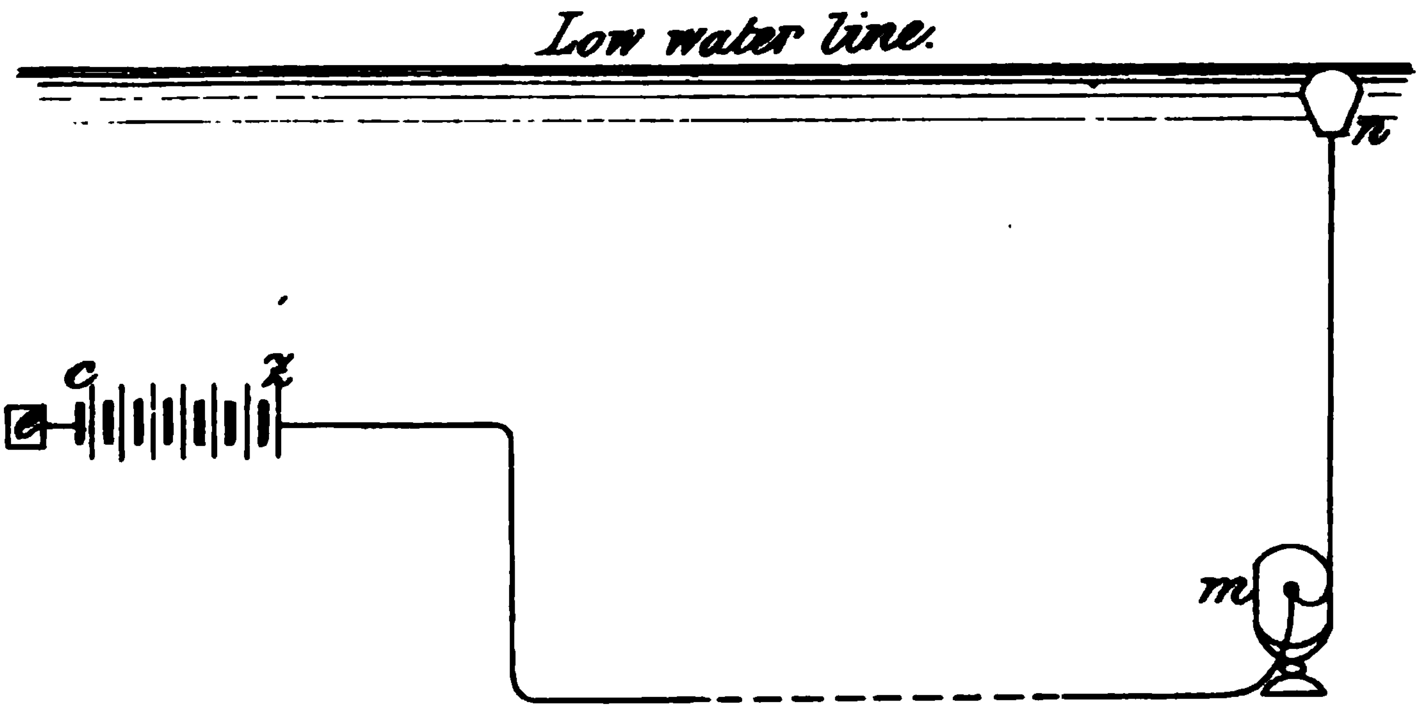
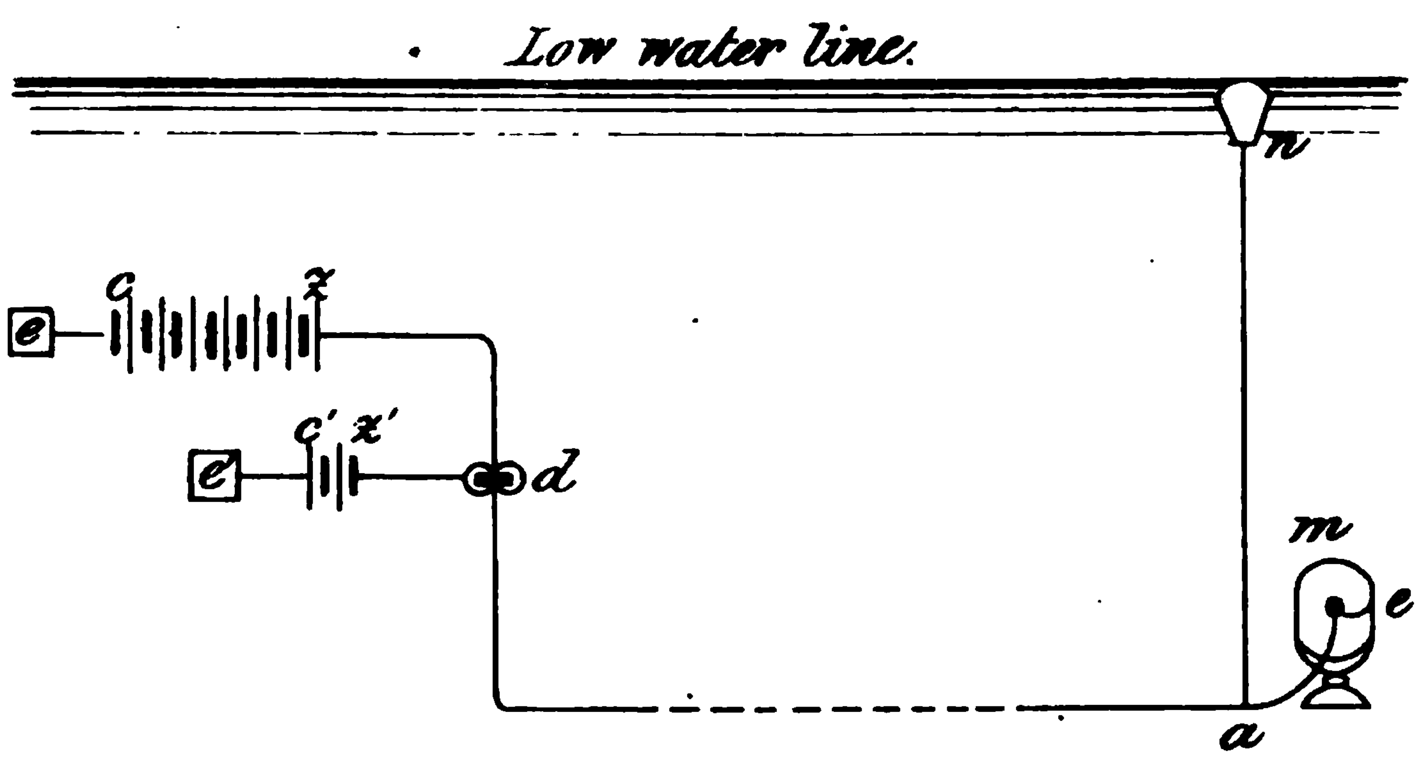


Fig. 2.



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B. Butler, Corpl. R. E.

closer, carefully to insulate the fracture, the charge *m* would, under such circumstances, probably be harmless. It might possibly be fired by induction with the frictional machine, as already described, if there were a sufficient length of conductor beyond the fuze, between it and the circuit closer, and a suitable fuze were used, but this would be a difficult and uncertain result to obtain. That it might be done, however, under certain conditions, is proved by the result of the last experiment detailed in page 122.

In order to obviate such a contingency, a different combination has been proposed by Quarter-Master Sergeant Mathieson, R.E., which is well deserving of attention, from the great ingenuity displayed in all its arrangements. *Plate* LXXIV., *Fig.* 2, shews the general design of the system described in detail at page 151 and those following, which has been adopted by the Torpedo Committee, for the service 250lbs. and 300lbs. mines, with detached circuit closers. The electric cable passes direct from the battery *c z* to one terminal of the fuze in the charge *m*, the other terminal being directly connected to earth; there is also a branch to the circuit closer *n*, starting from a point *a* between the battery and the fuze. In this case the circuit closer is simply used as an indicator, and may be made to work a relay or shutter apparatus *d*, by means of a signalling battery *c′ z′*, of two cells, connected to earth at *e′*, in a manner to be hereafter described. When in a state of rest, the extremity of the cable passing from *a* to *n* is manifestly insulated, and it is evident that the charge *m* may be exploded at any moment at will, by simply completing the circuit of the firing battery *c z* in the testing room. Let us now suppose that an enemy, knowing the system of firing adopted by the defenders, has got possession of the circuit closer *n*, he would under such circumstances detach it, and having removed the insulation from a considerable portion of the extremity of the conducting wire, he would throw it into the sea, so that the current, finding an easier path through the bare end of the wire than through the fuze, would pass almost entirely in that direction and not fire the fuze. To obviate the chance of such a contingency, Quarter-Master Sergt. Mathieson proposes to introduce one of the mercury cup disconnectors, described at page 128, into the circuit, between the circuit closer and mine. If an enemy, therefore, were to get possession of a circuit closer attached to a cable arranged in this way, and cut and cast it off, under the supposition that he was connecting the circuit to earth and thus rendering himself secure, the falling away of the mercury would ensure the insulation of the point and the mine *m*, *Plate* LXXIV., *Fig.* 2, would still remain as efficient as ever. The disconnector arranged with the platinized metal cup and ball, described at page 129, would be equally effective if similarly applied.

Electro-magnetic disconnector.

Suppose now that an enemy, knowing that an arrangement of the nature above described was used, were to get possession of a circuit closer, he would carefully detach it, make the end of the wire bare, so as to complete the circuit to earth, and buoy it so as to keep the ebonite cup upright, and retain the mercury or platinized ball in such a position as to complete the circuit. To guard against such a contingency, another arrangement has been suggested by Quarter-Master Sergeant J. Mathieson. He proposes to introduce an electro-magnet between the fuze in the mine and the circuit closer, the armature of which should be in connection with a spring, arranged as in the primary circuit of Rhumkorff's induction coil, so that it would make and break the circuit mechanically with great rapidity. With such a combination as this it is easily seen, that every alternate instantaneous current would pass through the fuze in the mine *m*, *Plate* LXXIV., *Fig.* 2, and fire it. With such an arrangement, it would not matter whether an enemy were to insulate the wire, after detaching the circuit closer, or not, as the power of firing the charge at will would remain in the hands of the defenders under both conditions. It would not, however, be available for use with the frictional machine.

Further trials required.

These disconnecting arrangements, in the form described, have none of them been sufficiently tried to enable a definite opinion to be given as to their practical use. They are, nevertheless, interesting, as illustrations of the general forms of combinations which might be used, to counteract an enemy's attempts to render a system of submarine mines ineffective.

There is no doubt that it would be a very great waste of power to fire large mines, of 500lbs. of gun-cotton, for example, at boats engaged in searching for them, and such boats might, relying on the immunity thus secured, carry on their operations with comparative boldness. In daylight it is probable that they might be kept off by the guns covering a system of mines, or by boats manned by the defenders, but at night, or in a fog, they might carry on their operations in comparative security as regards such means of defence; the question is, therefore, whether some plan might not be adopted to act as a deterrent without, at the same time, sacrificing the principal mine. It has been suggested, for example, that a small charge, sufficient to sink a boat without damaging the large charge, might be placed in the circuit closer, and arranged to be fired when that circuit closer was touched. In order to secure this effect, some such combination as the following might be adopted. A single fuze might be placed in the charge in the circuit closer, the latter being connected, as shewn in *Plate* LXXIV., *Fig.* 2, with a branch circuit from the point *a*, while in the main charge a number of fuzes might be placed in continuous circuit, or with a considerable electrical resistance, in the shape of a coil, or an ordinary lightening protector might

Suggested arrangement of small charge in circuit closer

be arranged between the point a and the fuzes in the charge m. Now, if a battery, sufficient to fire a single fuze, were arranged in connection with a circuit so constituted, directly the circuit through the circuit closer was completed, by touching the latter, the charge therein would be fired, and any small boat in its vicinity sunk or damaged; while from the great resistance introduced between the point a and the fuzes in the main charge, these latter would remain intact, but could still be fired by a considerable increase in the power of the firing battery, or by the frictional or dynamo-electric machine, provided the end of the branch connecting the point a with the circuit closer was insulated when blown off, and this could be effected by means of the mercury cup or other combinations already described. This arrangement is simply a suggestion, and has never been tried. For the present, it is intended to guard the mines at night by gunboats, used in combination with some means of illuminating their position by the electric or other powerful light.

Difficulties attending use of charge in circuit closer.

The arrangement of the small charge in the circuit closer, must be attended with difficulties. In the first place, it becomes necessary so to balance the respective resistances of the fuze in the circuit closer and those in the main charge, as to render the simultaneous explosion of the two charges impossible. To do this, a largely preponderating resistance must be given to the circuit in the main charge, and in order subsequently to fire the latter with certainty, a very large increase of battery power would be necessary. This adjustment of resistances in the fuzes, as well as subsequently in the battery power, would at all times be a delicate operation and require the greatest care. Again, the circuit closer must be at such a distance from the mine itself, that the explosion of the charge contained in it shall not damage the case or connections of the latter. A charge of 5lbs. of gun-cotton would probably be sufficient to sink any boat, but it would be necessary to ascertain how far such a charge must be placed from others in its neighbourhood to ensure their safety. Again, it is not desirable to expend the circuit closer attached to a mine, except as a last resource, because as soon as it is gone the mine can only be fired by judgment. It is a choice of evils, however, and preferable to allowing an enemy to carry off the circuit closer without damage to himself.

In order to determine whether such a system can be practically worked, carefully conducted experiments are necessary.

Advanced line of contact mines for defence against boats.

The chief mode at present proposed for keeping off boats is to place a line of contact charges, in advance of the main line—a line of outposts as it were. There can be no doubt that the sinking of a few boats would produce a very salutary effect as regards the defence.

If these charges were sufficiently large to damage, if not to sink,

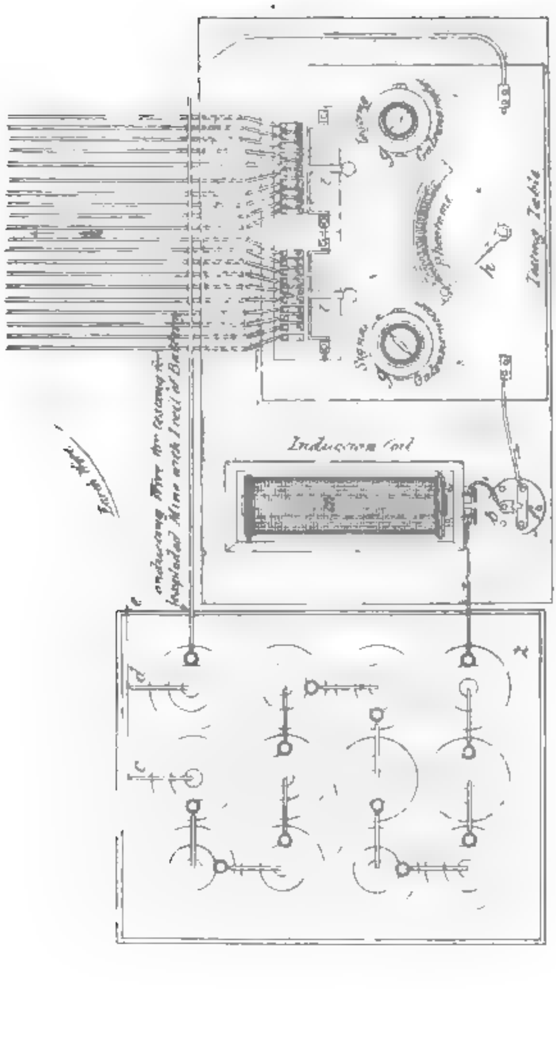
vessels of any size, a further advantage would accrue. Contact charges of 100lbs. of gun-cotton would not be very bulky to handle and would no doubt be effective, in an advanced system of this sort, even against vessels of the largest size; and if exploded by the smaller craft their loss would not materially affect the main defence.

Use of rope and net obstructions.

A series of experiments, to test the value of rope and net obstructions, in keeping off boats or even larger vessels, has been carried on by the Germans in the Bay of Jahde. They seem to place much reliance on defences of this sort for the purpose required, and there is no doubt, where they can be maintained without an exorbitant amount of labour, they would be very effective in stopping the progress of vessels propelled by screws. The chief difficulty attending their use seems to be their liability to be injured by storms, if placed in exposed situations.

PLATE LXXV.

AUSTRIAN TESTING TABLE.



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CHAPTER XII.

Electrical Testing Tables, &c.

We now come to the consideration of testing tables, or in other words, the mode of arranging the wires, in connection with the charges, in a convenient form in the electrical room within a fort. When a very large number of wires must be introduced into a fort, it becomes necessary to arrange them in such a manner that they shall be easily identified, and that the operations of testing and firing, &c., may be conducted with the greatest amount of simplicity. Several forms of tables have been designed with this object in view. The Austrian government exhibited several instruments of this nature at Paris, in 1867; one of these, which gives a good general idea of their system, may be described as follows:—

Austrian testing table.

Its design is shewn in *Plate* LXXV.; *c z* represents the battery with one pole to earth at *e*, and the other in connection with an intensity coil *a*, through which the current passes to the contact plate *b*. When it is desired to put the system of mines, in connection with the table, in a state of preparation to be fired by the contact of a vessel, a plug is inserted between the contact plates *b* and *f*, and the current passes through the galvanometer *g*, and electrically charges the conducting wires connecting the mines with the battery, through the several binding screws on the contact plates, numbered 1, 2, 3, &c.; as soon, therefore, as a vessel makes contact, the circuit is completed, as already described, (see page 234), and the charge fired. The fact that a charge has been fired, is also at once indicated on the galvanometer *g*.

Test to discover an exploded charge.

It then becomes necessary to ascertain which particular mine of the system has been exploded; for this purpose a separate circuit, in connection with a single cell, *d*, is employed. This cell is in connection, through a galvanometer *g′*, (a more sensitive instrument than the galvanometer *g*), with the pivot of the key *h* and Rheotome, which latter is connected, as shewn by the dotted lines, with each individual mine of the system attached to the contact plates numbered 1, 2, 3, &c. The handle of the

Rheotome is moved round to each number in succession, and directly it is placed in contact with that corresponding to the exploded mine, the electrical circuit is completed, through the exposed end of the fractured conducting wire in the sea water, and this is indicated by the deflection of the needle of the galvanometer g'. There are numbers on the Rheotome to correspond with those on the front contact plates, so that the number of the exploded mine is at once indicated: the circuit in connection with it should at once be detached, by disconnecting the insulated conductor attached to it from the binding screw on the front contact plate. During the testing process the firing battery $c\ z$ must be disconnected; this is done by raising one of the bridges i, i, with which each group of 10 mines is provided. The process of testing for an exploded mine does not occupy much time: as soon as each group of 10 has been tested, the bridge corresponding with it is dropped, which throws it at once into circuit with the firing battery. Each group of 10 mines has an independent electrical connection with the firing battery, so that each section may be tested separately, and only that undergoing this process is out of circuit, the remainder being free to act if struck by an enemy's vessel. The simple raising of the bridge i of any particular group of mines, by throwing the whole of them out of circuit with the firing battery, would at once indicate, by the cessation of deflection on the galvanometer g, the particular group to which the exploded mine belonged, and the actual mine itself could then be picked out by means of the Rheotome and galvanometer in the testing circuit.

Insulation test.

The Rheotome h and testing galvanometer g,' are also used to test the insulation of the electric cables connecting the mines to the testing table. This is done in precisely the same manner as testing for an exploded mine: the handle of the Rheotome is turned round, and each cable connected, in succession, with the testing circuit as before; should the galvanometer g' remain stationary, the insulation is good; but should a defect of insulation exist, the current passing through it would act on and deflect the galvanometer, indicating the particular line in which it exists, and, roughly, its extent in proportion to the deflection shewn; should the fault be considerable, the defective cable should be at once detached, as the current lost through it might so diminish the working power of the firing battery, as to prevent its exploding any of the fuzes attached to the group in connection with it. By the above arrangement, the insulation of each line can be tested at any moment required.

In making a delicate test for insulation, which should invariably be done at leisure and, if possible, when an enemy's vessels are not in the vicinity of the mines, a large number of Daniell's or other cells of suitable form should always be used. To do this, it would only be necessary to connect such a battery in

TESTING TABLE.

Fig. 1.

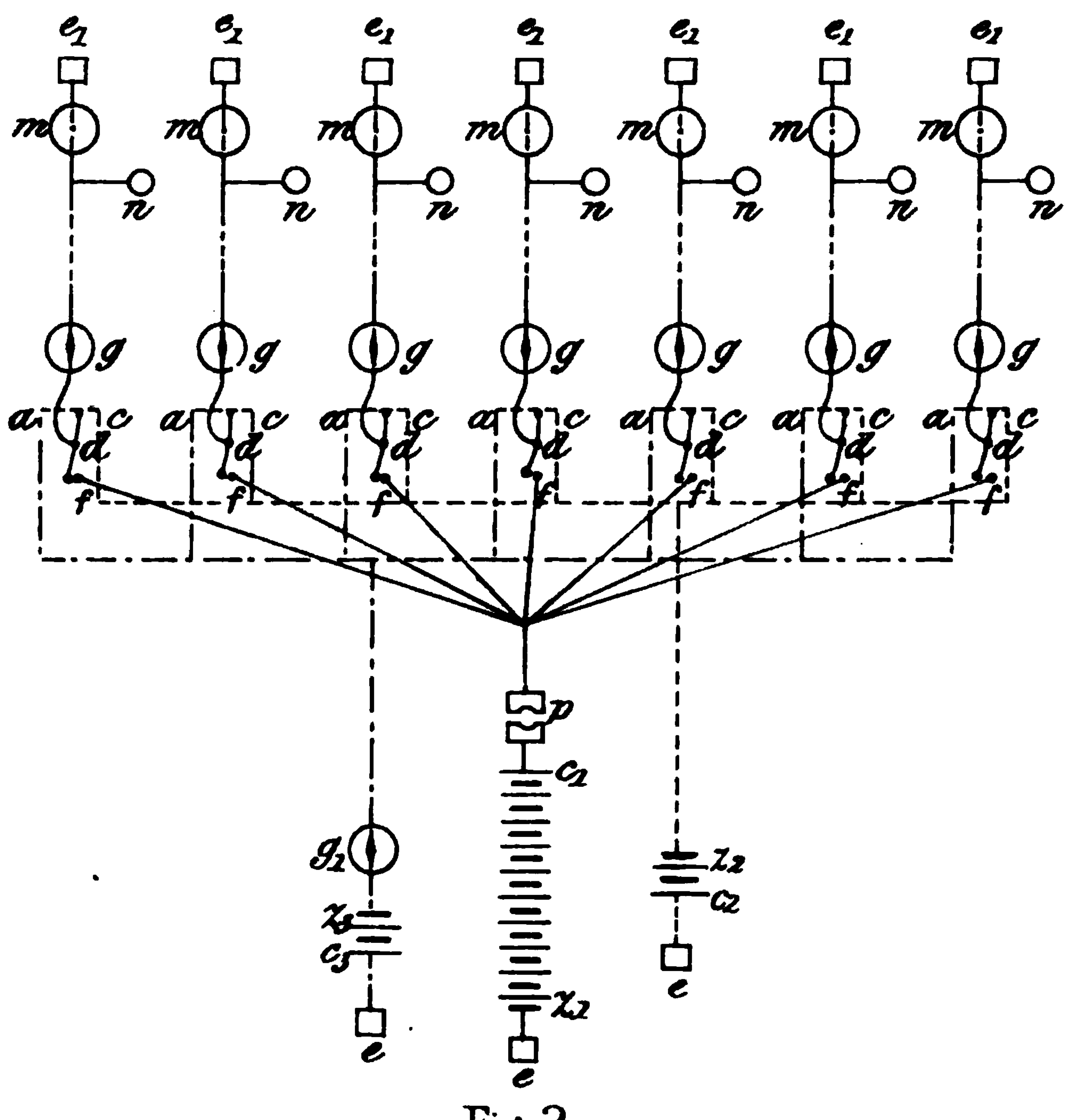
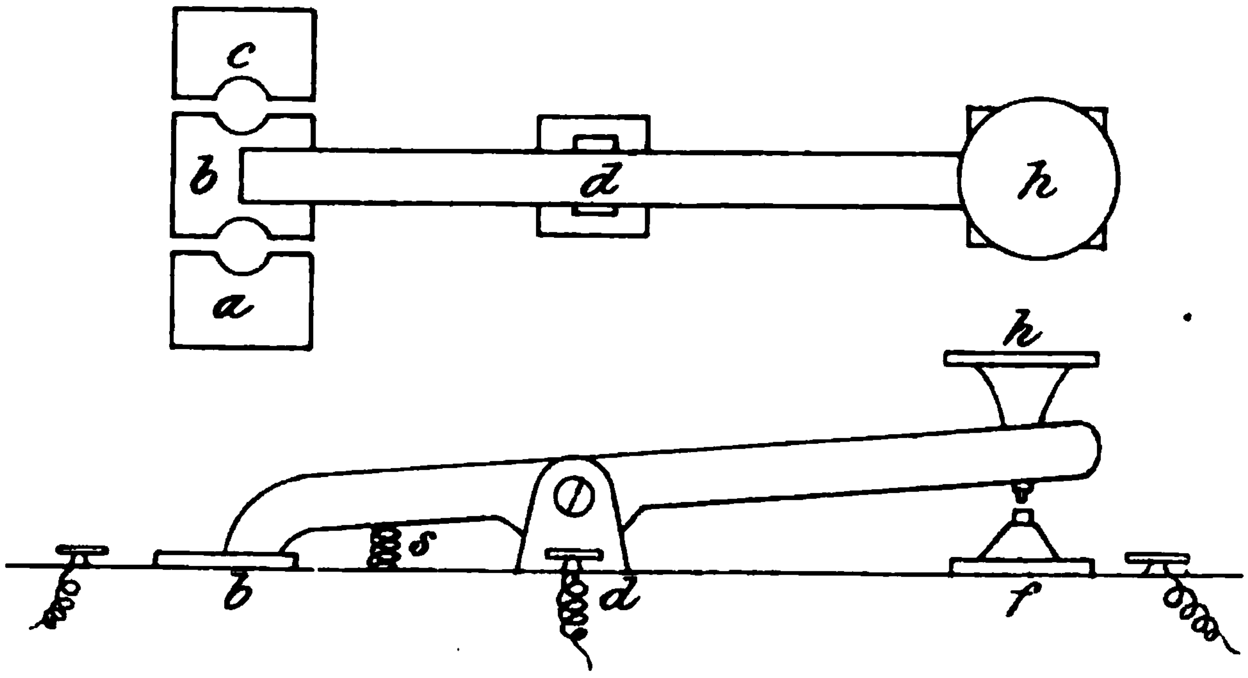


Fig. 2.



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place of the single cell permanently arranged, as described, in the testing circuit, and to proceed with the details of the operation as before. As the cable would, in actual work, always be charged with the full power of the firing battery, the value of its insulation to resist an electrical charge at such a high potential would be an important point to determine. The fuzes being entirely out of circuit till the moment of the action arrives, no danger of a premature explosion need be apprehended; if a fuze were in such a position as to be fired prematurely, it would be exploded, in connection with the firing circuit, independently of the operation of testing the insulation of the cables.

To render a channel safe.

In order to make the channel safe for a friendly vessel, it is only necessary to remove the plug from between the contact plates *b* and *f*; this disconnects the firing battery from the circuit.

Great care should be taken to keep the metal bridges *i i* always in their place, and making good contact, except at the moment when required to be raised for testing purposes, in order to avoid the chance of a failure of the firing battery at the right moment.

The form of testing table described is that used in connection with the Austrian self-acting system of contact mines. Other combinations adapted to various conditions, such as firing by judgment, &c., were also exhibited.

Testing table where firing battery is put in circuit by hand.

A simple arrangement of testing table is shewn in *Plate* LXXVI., *Fig.* 1. In this combination a series of metallic points *d*, *d*, *d*, &c. are in metallic connection, through a series of galvanometers *g*, *g*, *g*, &c., with the line wires, fuzes in the mines *m*, *m*, *m*, &c., and earth plates, e_1, e_1, e_1, &c. The galvanometers, *g*, *g*, *g*, &c. are not very sensitive, just sufficiently so as to indicate directly the passage of such a current as would be produced by closing the circuit of a battery of 2 or 3 Daniell's cells, as c_2 z_2, by the action of a circuit closer, one of a set placed on a series of branches as *n*, *n*, *n*, &c., so as for the moment to cut out the resistance of the fuzes in the mines *m*, *m*, *m*, &c. in the manner already described. Another series of contact points *f*, *f*, *f*, &c. are in connection with one pole of a firing battery c_1 z_1 the other pole being to earth. In order to fire any of the mines at will, it is evident that it only remains to close the circuit of the battery c_1 z_1 by completing the connection between the points *d*, *d*, *d*, &c. and *f*, *f*, *f*, &c, this is effected by the simple depression of a key which is arranged to be done by hand. Another set of contact points *a*, *a*, *a*, &c. are in connection, through a very delicate galvanometer g_1, with a testing battery c_3 z_3. *Fig.* 2 shows an enlarged plan and elevation of a firing key. Contact plugs are provided which, in their ordinary position, would remain between the contact plates *b* and *c*; and the front arm of the firing key being in connection, when in a state of rest, with the point *b*, and pivoted on the contact point *d*, the current of the signalling

Testing and signalling circuits.

battery $c_2 z_2$, which is always kept in metallic connection with the plate *c*, would be free to pass through the contact points *c*, *b*, and *d* and along the line wire; and the completion of any individual circuit through its own circuit closer would be indicated on its corresponding galvanometer of the series *g*, *g*, *g*, &c. In order to test any individual line and fuze it would only be necessary to remove the contact plug from between the plates *b* and *c* and insert it between *a* and *b*, by which operation the signalling battery $c_2 z_2$ would be thrown out, and the testing battery $c_3 z_3$ and galvanometer g_1, which are in metallic connection with the plate *a*, would be thrown into the circuit, and the degree of deflection of the latter would indicate whether all was right as regards insulation and conductivity. During this process of testing, it will be observed that the line and charge tested would only be thrown out of the ordinary conditions, the remainder of the charges would remain in *statu quo* and be ready to indicate that a vessel was within the radius of destruction at any moment. The ordinary galvanometers *g*, *g*, *g*, &c. would at all times give a rough indication of the effectiveness or otherwise of the line and fuze.

Firing key.

The key employed for firing, is precisely of the form used with the ordinary Morse telegraph instrument. In a state of rest the front contact is held down on the plate *b* by means of a spiral spring *s*, and to fire, it is only necessary to depress the handle *h* and make contact with the plate *f* and, the key being pivoted on the point *d*, the effect of this depression would be simultaneously to break contact with the point *b*. Thus, the firing battery would be thrown into circuit and the signalling battery cut out simultaneously by the depression of the key.

To detach circuit of expended charge.

When any given charge had been fired, it would only be necessary to remove the plug from between the plates *b* and *c*, in order to cut off the conducting cable, which would otherwise interfere detrimentally with the action of the intact circuits, and which, after a charge has been fired, should be detached with as little delay as possible. If the circuit were cut off in this way, the line wire itself could be disconnected from the system at leisure, an operation which it might not be convenient to perform immediately, in the heat of action, with an enemy's vessels in the act of passing over the mines. In this system it will be observed, that the firing battery is only thrown into circuit at the wish of the operator, and that no mine can be exploded without the depression of its corresponding key; in order, however, to render the system perfectly safe, and to guard against the accidental depression of a key, which would produce a premature explosion, a plug has been provided, between the firing battery and the apparatus, at the point *p*; when this plug is out, the firing battery cannot be accidentally thrown into circuit.

ORIGINAL DESIGNS FOR SHUTTER SIGNALLING APPARATUS.

Fig. 1.

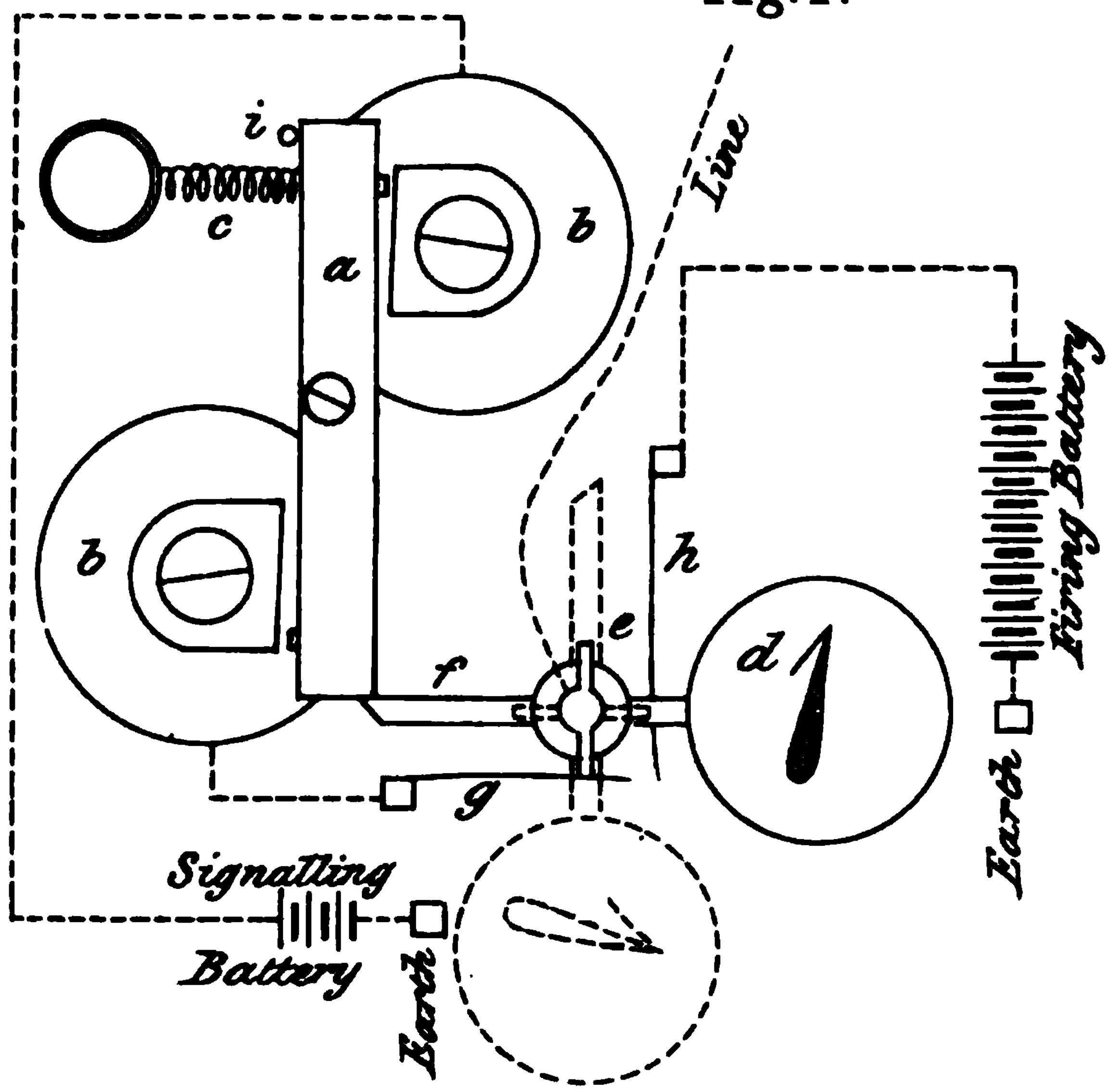
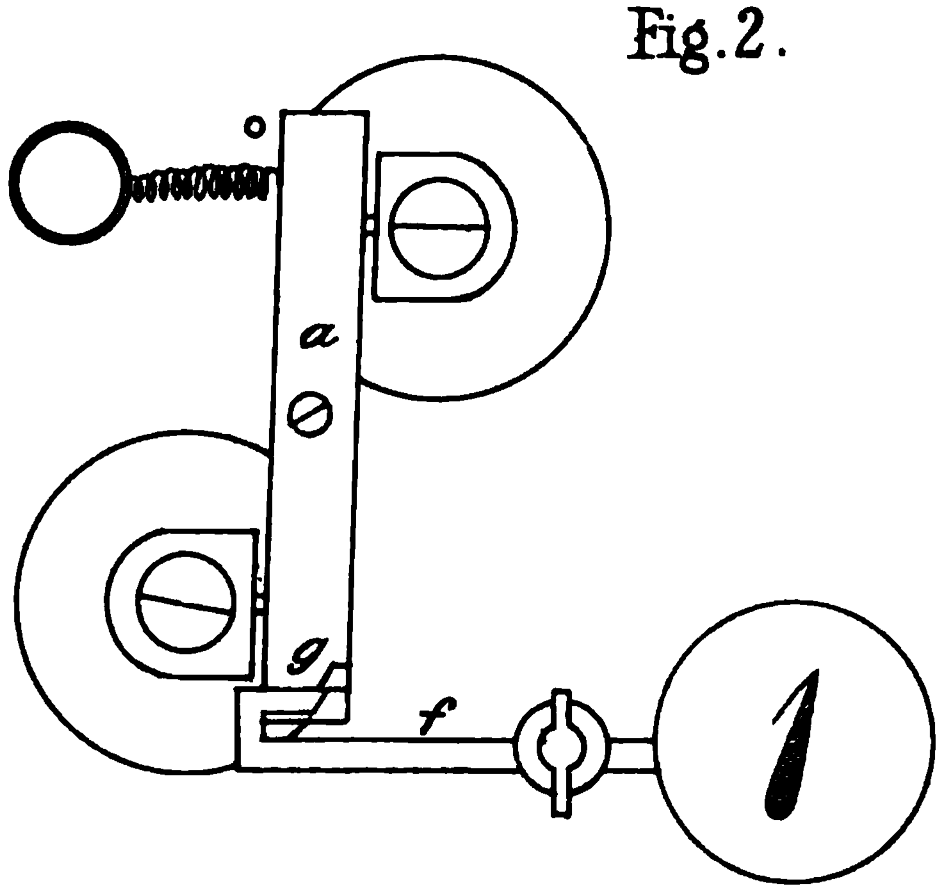


Fig. 2.



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The construction of a testing and firing table of this nature is so simple, that it could be very easily put together by an ordinary workman, and the materials of which it is composed are obtainable anywhere. The mines in connection with it are capable of being fired by judgment and, for this purpose, would only require the addition of signalling apparatus, somewhat similar to that described in page 223, and those following, to complete the system, which could thus be used for firing by intersection when the position of the mines was clearly visible, while capable of being used at night or in a fog, on the signal being made by a vessel in contact, as first described. It is, however, dependent for effective service upon the vigilance and dexterity of the man in charge, which is a defect common to all systems in which firing by judgement is employed.

Construction of such a test table very simple.

This arrangement of testing table may be used either on the circuit closing or circuit breaking system. With the circuit closing system, it would be connected precisely as shewn in *Plate* LXXVI., *Fig.* 1; with the circuit breaking system, the circuit breaker would be placed beyond the fuze, and the signalling current passing through it would keep the galvanometers deflected. On a vessel striking any one of the circuit breakers, the action on the corresponding galvanometer would cease, and its needle would fall back to the position due to terrestrial magnetic attraction, and this motion of the needle would indicate the fact of the ship's contact.

May be used either with a circuit closing or circuit breaking system.

The system above described, is so arranged as to indicate a vessel in contact with a circuit closer, and as in many cases it may be convenient, or even necessary, to perform the operation of throwing in the firing battery, without the aid of a personal operator, a self-acting system has been devised, in which the firing circuit is closed automatically, by means of an instrument called the "shutter signalling apparatus." By making the apparatus purely self-acting, all chance of error, consequent upon the inattention or want of dexterity of the man in charge is, of course, eliminated, and this may be done without complicating the connections of the instrument to any considerable degree.

Plate LXVII., *Fig.* 1, shews a diagram of the original idea for the arrangements, by which a vessel striking a circuit closer may be made to shift, by means of a relay, the conducting cable from the signalling to the firing circuit and explode the charge. The apparatus now approved for service has been considerably improved upon this original, though the principles of action remain unchanged.

Shutter signalling and firing apparatus.

a is an armature, working on a pivot between the two horns of an electro-magnet *b*, *b*, and held in position by a spiral spring, *c*; the latter is in connection with a regulating screw, by which more or less pressure may be brought to bear in an

opposite direction to that of the attractive action of the electro-magnet. A small stud *i*, regulates the distance to which the armature may be drawn back; *d* is a shutter, on which a reference number is clearly indicated, attached to a lever pivoted at the point *e*, the inner arm of which is just long enough to catch under the point of the armature *a*: when a current is passed through the coils *b*, *b* of the electro-magnet, the armature *a* being attracted, the lever attached to the shutter is released and the latter falls by its own weight into the position shewn by the dotted lines. The pivot *e* is formed of an ebonite cylinder, with a metal centre, from which latter two metal points project through the ebonite. When the lever *f* is held up by the armature *a*, one of these metal points projects downwards and is in contact with a metal spring *g*, which forms a portion of the circuit of the signalling battery. When the shutter falls into the position indicated by the dotted lines, the other metal point, projecting through the ebonite cylinder, comes in contact with a metal spring *h*, which forms a portion of the circuit of the firing battery, while the connection between the spring *g* and its corresponding point is broken, in consequence of the revolution of the pivot bringing the ebonite part of the cylinder upon it. The metallic portion of the axis *e*, being permanently connected with the line wire terminal, and through it with the electric cable and fuze in the charge, it is easily understood how the action of dropping the shutter throws the firing battery into circuit, and simultaneously cuts out the signalling battery and explodes the mine. The points of the metal projections on the pivot *e* and the faces of the springs *g* and *h* are platinized, to prevent oxide and ensure good metallic contact between the parts. The armature *a* is prevented from coming into actual contact with the horns of the electro-magnet, by two small studs: the object of this is to prevent any effect of residual magnetism which might interfere with the adjustment of the counter spring, in cases where the armature had been called into action by passing vessels.

Constitution of signalling battery.

The signalling battery should be so constituted, as to be capable of working the electro-magnet effectually when the circuit is closed direct to earth, and attracting the armature with sufficient force to release the lever *f* with certainty, and yet not so powerful as, by the continuous passage of the current generated by it, to fire the fuze in the mine. Plenty of power may be given to this battery, when used in connection with a platinum fuze, without any chance of accidental explosion from this cause, but where a high tension fuze is employed it is necessary to be careful in order guard against such a contingency.

Testing arrangements.

Testing arrangements, very similar to those shewn in *Plate* LXXVI., *Fig.* 2, were used with this apparatus; it was however necessary to disconnect the firing battery when testing, as any accidental dropping of the shutter would have produced a

premature explosion. In the form of shutter apparatus adopted for service, this defect has been overcome. Except when an enemy is in the vicinity of the mines, however, it is always a good precaution to detach the firing battery when testing operations are going on.

Firing battery.

The firing battery should be suited to the nature of the fuze employed, and should possess considerable excess of power in order to overcome accidental defects, such as increased resistance in the connections or defective insulation in the electric cable leading to the mine. A battery, just sufficiently powerful to fire a fuze on shore, with the electric cable, &c., in circuit, but not submerged, would not be unlikely to fail after the cable had been immersed in sea water; in such a case it is recommended that the battery power, determined by such an experiment on shore, should be doubled for actual work.

Mode of action of the apparatus.

If used in connection with a group of mines, arranged with circuit closers, as shewn in *Plates* XVI. and XVII., the mode of action of the apparatus would be as follows:—while at rest the current of the signalling battery would be divided between the several fuzes in circuit; each of these fuzes, possessing a very high electrical resistance, would, by its presence in the circuit, prevent the battery current, passing through the coils of the instrument, acting with sufficient force to form an electro-magnet, sufficiently powerful to overcome the resistance of the spring *c* and draw the armature *a* over to it. Directly, however, one of the circuit closers was struck, the whole of the fuzes would be, for an instant, practically cut out of circuit, because the resistance of those fuzes, compared with that of the earth connection of the circuit closer, is so great that virtually the whole current would pass through the one particular circuit closer that had been struck. When this took place, the comparatively feeble current of the signalling battery would therefore practically be passed through a single electro-magnet, (that in connection with the circuit closer struck), and would consequently act with sufficient force to attract the armature, which it had not power to do when divided between the several fuzes, (each possessing a very high electrical resistance), in the group. The armature *a* being attracted, the lever *f* would be released, the shutter would fall, and the firing battery would be thrown into circuit, through the spring *h* and the metal point in contact with the pivot *e*, the coils of the electro-magnet being simultaneously cut out of circuit, as already described, the current of the firing battery, having a direct metallic circuit through the fuze to earth, would pass instantaneously through, and fire the mine. The action of the whole is so rapid that practically the instant a vessel struck the circuit closer the mine would be fired.

In order to test the capabilities of the shutter arrangement for standing the concussion of heavy guns fired in its vicinity, ex-

Experiments to test stability of shutter signalling and firing apparatus, during concussion produced by firing guns.

periments were tried at Sheerness, with a working model constructed on the principles above described. It was placed on the parapet of the work, at a few yards distance, during artillery practice with a 7-inch muzzle loading rifled gun; subsequently advanced close to the muzzle of the gun, and finally placed on the gun platform, and the only case in which the shutter fell was when the whole apparatus was knocked over by the recoil of the gun. The instrument was made to work by closing the circuit electrically between each round, in order to ascertain that its stability was not caused by any undue tension of the regulating spring.

It would seem therefore that, with moderate care, there would be no danger of a shutter dropping by concussion, but experience has proved that it is necessary to balance the force of attraction, exercised by the electro-magnet, against the mechanical effect of the spring, with some degree of nicety, as in guarding against an accident due to the falling of a shutter, one is sometimes apt to apply the spring too strongly.

Several modifications of the shutter signalling apparatus have been proposed and made, but before any one of them can be considered sufficiently perfect to be received into the service, further experiments to determine their action when subjected to the effect of concussion, produced by the firing of heavy guns, must be made. Though the experiments tried at Sheerness were sufficiently conclusive as to the particular specimen tested, it is necessary that the instrument should be thoroughly tried, under every possible condition which might occur in actual work. The stability of the shutter is a point vitally essential to its use, as in many instances it would be impossible to put it in such a position as to be out of reach of concussion. The question of the stability or instability of the shutter, involves a condition of balance between the force exerted by the regulating spring, pulling the armature in one direction, and the attraction of the electro-magnet, acting in the opposite direction. In the circuit closing system, the spring must hold the armature sufficiently firmly, to prevent the accidental fall of the shutter by concussion, while the battery must be so constituted as to act effectually when the circuit is closed. In the circuit breaking system, the battery must, on the contrary, hold the armature steady, while the spring ought to be able to act with sufficient force the moment the circuit is broken. It is not desirable to draw absolutely definite conclusions from the single experiment referred to, even though it was a very severe one on the instrument, and the conditions were infinitely less favorable than those which would ever occur on service.

Shutter signalling apparatus

When the circuit breaking system is used with the shutter signalling apparatus, the action of the armature in releasing the lever must be reversed; that is to say that when the current

ORIGINAL DESIGNS FOR SHUTTER SIGNALLING APPARATUS.

Fig. 2.

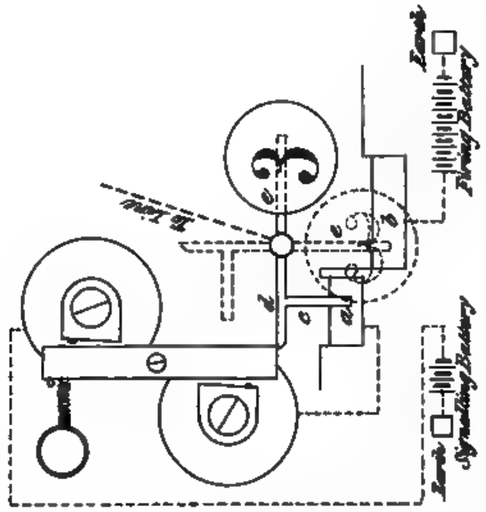
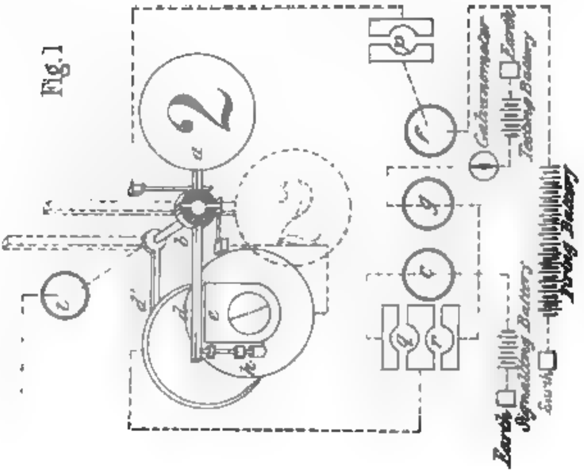


Fig. 1



Lithographed at the S. M. E., Chatham. B. Butler, Corpl. R.E.

is passing and the armature attracted to the horns of the electro-magnet, the shutter must be held up, and when the current ceases and the armature is drawn back by the action of the spring, it must release the lever and allow the shutter to fall. This may be done by the arrangement shewn in *Plate* LXXVII., *Fig.* 2: the extremity of the lever *f* is bent up and passes round and under a projection *g*, attached to the lower portion of the armature *a*; when, therefore, the current ceases for a moment and the armature falls back, carrying the projection *g* with it, the lever *f* is detached, and the shutter becomes free to fall. The projection *g* and the extremity of the lever *f* were made wedge form, in order the more readily to become disconnected from each other when the apparatus is put in action.

for circuit breaking system.

Another form of shutter signalling apparatus, proposed for use with a circuit breaker, is shewn in *Plate* LXXVIII., *Fig.* 1. In this instrument the shutter *a* is pivotted on a metal axis *b* with two projections, insulated, as before, with ebonite. The electro-magnet *e* is, in this case, composed of a single coil, and two levers, *d* and *d'*, one attached to each extremity of the axis *b* on which the shutter is pivotted, are so arranged that they may be attracted to and held by the electro-magnet as long as the current is passing, *d* being held by the front and *d'* by the rear point of the electro-magnet. A small capstan-headed screw *h* regulates the distance between the electro-magnet and the armature; it prevents absolute contact, which might be detrimental in the case of residual magnetism, and by it the sensitiveness of the apparatus may be regulated. When the current ceases the shutter falls down into the position shewn by the dotted lines, and, the springs and connections being precisely similar to those already described, the firing battery is thrown into circuit as before. *Plate* LXXVIII., *Fig.* 1, shews also the connections of the apparatus; *f* is the terminal to which the firing battery must be attached; *g* the terminal for the testing battery and galvanometer; *c* the terminal for the signalling battery; and *l* that for the electric cable to connect the fuze in the charge. A plug *p* provides the means of rapidly detaching the firing battery; this latter is entirely out of circuit, and no mine in connection with the group can be fired, unless the plug *p* is inserted between the two brass plates provided for it. A second plug is used to connect the signalling battery, by insertion, at the point *q*, between the brass plates provided for that purpose; if removed from *q* and inserted at the point *r*, the signalling battery is cut off from the circuit, and the testing battery is thrown in. When the plug *q* is taken out for testing purposes there would, of course, be a cessation of current through the coils of the electro-magnet, and the shutter would fall down and complete the circuit of the firing battery; to guard against such an accident it would be necessary, therefore, when testing,

Shutter signalling apparatus with straight electro-magnet.

previously to remove the plug p, or to support the shutter, for the time, by some mechanical means.

With the exception of the action of the electro-magnet, in dropping the shutter, being the reverse of that previously described, that is to say, dependent upon the cessation of the current and not on its action, the mode of operation of this apparatus is precisely similar to that already given, and need not therefore be again described.

Shutter signalling apparatus with mercury connections.

Another form of this instrument, which was at one time proposed, is shewn in *Plate* LXXVIII., *Fig.* 2. Its armature, electro-magnet, regulating spring, stud, shutter, and attached lever, are precisely similar to those first described, (see page 259), but the connections are made by two mercury cups a and b. When the lever is horizontal, and shutter drawn up and ready for action, the circuit of the signalling battery is completed through the mercury cup a, along an arm c, projecting downwards from the lever d, and thence to the shutter pivot and line terminal, as before. When the shutter is down, as shewn by the dotted lines, another arm e, a prolongation of the lever d, falls into the mercury cup b, which latter is permanently connected with the firing battery. The object of the mercury cups is to get rid of the springs in the original design, electrical circuits dependent on the pressure of springs being somewhat liable to interruption from dirt, or oxide, intervening between the points of contact. It was supposed that there would be much less danger of such a contingency if mercury cups were used. After a trial it was found, however, that they did not answer, and they have not been adopted in the form of apparatus approved for service. An electrical bell was placed in the firing circuit in the instruments first made, to give notice, by striking, when a mine had been exploded: this has since been replaced by a bell, arranged to act mechanically, and quite independent of all electrical connections.

Shutter signalling apparatus combined with firing keys.

The shutter signalling apparatus may be so arranged as to be worked on the circuit closing system, by a combination of firing keys, in connection with observing stations, as described at page 230. In this way the system has been arranged for firing by intersection when the position of the mines is distinctly visible, while no change of connections is necessary to render it self-acting.

Should the circuit breaking system be used, the combination would not be so simple. The visual circuit closing system is dependent on the closing of the circuit at two distinct points, while the breaking of the circuit at one point would cause the shutter to fall. If therefore a circuit breaking combination were used, it would be necessary to arrange an entirely separate system, on the circuit closing principle, for signalling: in this way the number of a mine might be readily indicated to an

operator, and he might throw down the shutter, or introduce the firing battery in any simple way, by hand.

If a system of firing by intersection, combined in this way with a self-acting system, were used, the observing stations would frequently be some distance from the testing room: they (the observing stations) ought to be, if possible, well clear of the smoke of guns in action, while the testing room ought to be within a fort and in a bomb-proof casemate, well covered from an enemy's direct and vertical fire. There would, however, be no difficulty in arranging a combined system under such conditions, either for the circuit closing or breaking system.

Arrangement of shutter signalling apparatus in box.

The shutter signalling apparatus may be conveniently arranged in a compact form, with a long box to contain the coils, which box should be made to shut up and lock, to prevent interference by unauthorised persons. The battery terminals, brass plates, plugs, etc., should be placed on a board in front and outside the box itself, so as to be accessible at all times. The coils of the electro-magnets may be conveniently placed side by side; in this way seven coils, with their necessary terminals, brass connecting plates, etc., may be arranged in a very convenient form, without being too bulky. Seven is a convenient number, there being seven cores in each multiple cable.

Approved form of shutter signalling apparatus.

After numerous experiments, a form of shutter signalling apparatus, of the construction shewn in *Plate* LXXIX., has been approved for service. It has been designed for employment in connection with an electrical system of submarine mines, in order to afford the necessary arrangement for firing the mines by judgement, or for making them self-acting, at pleasure. This idea was first indicated by the late Field Marshal Sir John Burgoyne, Bart., in his Memorandum, dated War Office, July 20th, 1863, to the Floating Obstruction Committee. He says, "To provide for the difficulty of knowing at the battery, when the ship is actually in contact with the mine, it may perhaps be possible to have some signal, sound, or small explosion in or near the battery, *produced by the contact*, that might give the required notice, or to place a certain number in a line, say 4 or 6, at such distances that it could readily be perceived that the ship in passing must be in contact with one, and *exploding all simultaneously*, the effect could hardly fail." The ideas indicated in the words italicised suggest a system of firing by judgement in combination with a self-acting arrangement.

Details of construction.

The shutter apparatus contains 7 indices, of precisely the same construction, and working on the same principles, as those already described in pages 259 and 262, and the description of one index will suffice for all. In each index there are two bobbins *a*, *a*, the helices of which are screwed at the back to a soft iron bar, the coils of the two bobbins forming one continuous circuit, the outward extremities of the pair of bobbins

are susceptible of being magnetised, with opposite polarities, when a voltaic current circulates through the coils. Between the horns of the electro-magnet a soft iron armature *b* is pivoted, and its upper left hand surface abuts against an adjusting stud *c*, when the armature is drawn over by a spiral spring *d*, in connection with a regulating screw *e*, by which more or less pressure is brought to bear on the armature in opposition to the attractive force of the electro-magnet produced by the current. To prevent the armature from coming into actual contact with the iron surfaces of the horns, when attracted thereto, and from being held there by the residual magnetism in the system, brass studs are let into the horns, so that the armature may readily fall back into its normal position on the cessation of the current. The insulated wire *f* from the upper bobbin is in connection with the spiral adjusting spring, and consequently with the armature itself. The lever of the shutter *g* abuts against a stud in the front face and lower portion of the armature, the points of contact being platinised. The pivot of the lever is in direct circuit with the right hand terminal or main line connection on the top of the box. The insulated wire *h*, from the lower bobbin, is in connection with the middle brass plate *k*, in the front ledge of the apparatus. The circuit is now complete from the brass plate *k* to the main line terminals on the top of the box. The front and adjoining brass plate A, is provided with a terminal for connecting up the negative pole of the shutter battery, the positive pole being to earth. Now when the plug is placed in the hole *l*, between the front and middle brass plates, the shutter battery charges the coils of the shutter apparatus, and the main conducting cable to the submerged mine. The innermost brass plates, H, H, in the front of the apparatus, are all connected in the same metallic circuit, and to them are attached, by means of a binding screw D, the test battery and test galvanometer. Thus when the plug above-mentioned is shifted from the front *l* to the rear plug hole *m*, the shutter battery is cut out of the circuit of that particular mine, and the test battery thrown in. In this way, the tests of each individual charge can be readily taken, while the connections of the remaining mines are left undisturbed. The positive pole of the firing battery, (the negative pole of which is put to earth), is connected to the firing terminal at the right hand corner of the box on the lower ledge.

Connections of shutter signalling battery.

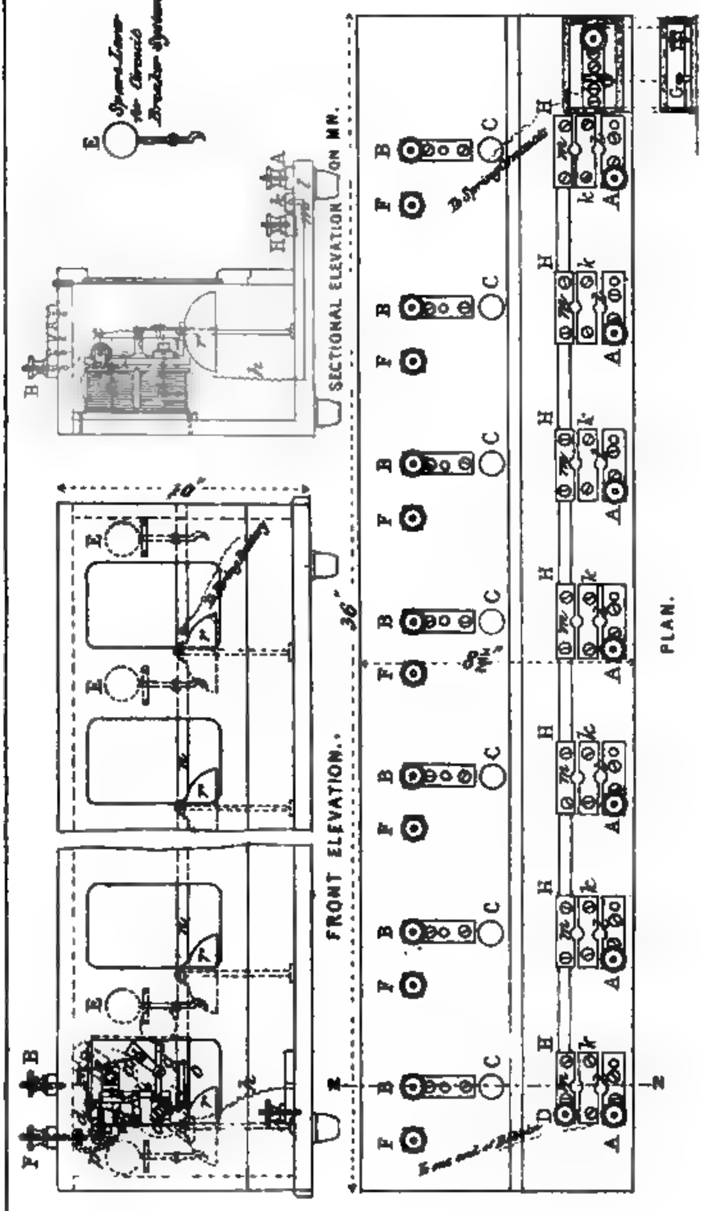
Connections of testing battery.

Connections of firing battery.

The firing battery is connected, by means of a binding screw, at the opposite end of the front of the wooden box, and is provided with a disconnecting plug G, by means of which the battery may be very rapidly thrown out of circuit. When the plug G is in at the firing connections, the brass bar *n* running horizontally the whole length of the apparatus, is charged. This bar is so fixed under the pivot points of the levers, and has contact jaws *o*, so situated under each lever, that on the dropping of the

PLATE LXXI

SHUTTER SIGNALLING APPARATUS,
APPROVED FOR SERVICE.



Lithographed at the S. M. E., Chatham. *B. Butler, Corpl R*

shutter, its lower portion g falls into the jaws o, and makes metallic contact therewith. When, from any cause, the lever drops, it is evident that the firing battery will be thrown into metallic connection with the corresponding cable to any particular charge. The lever carries a disc, to which should be gummed a paper numeral identifying the number of the mine connected to it. Ivory tablets, C, C, C, on the top of the box, are also provided for the same purpose, to indicate the number of the mine. From the brass plate, supporting the adjusting screw and spiral spring, a connecting wire p is taken to an additional terminal F on the top of the box, being the left hand terminal of the pair belonging to each index and mine. From this latter terminal, a wire may be carried to the connections of the observing telescope, for firing by judgment. From the above description it will be observed, that when the shutter battery and firing battery are in circuit, by the insertion of their respective connecting plugs, if from any cause an earth connection is momentarily established in the circuits, either in connection with the main line terminal B or the observing terminal F, the current from the shutter battery will for that moment circulate through the bobbins to earth; their cores will thereby be momentarily magnetised and the armatures will be attracted. This will release the end of the lever which has, till now, been held in a horizontal position, by resting against the catch in the front face of the armature; it will then fall into the jaws o of the firing circuit, and the disc at the extremity of the lever will strike the bell r, which is arranged to signal that a shutter has fallen. The firing battery will thus be thrown into the main line to fire the charge, and at the same moment the circuit of the shutter battery and the circuit to the observing telescope will be broken, the lever abutting against the catch h in the armature having been disconnected therefrom. This is the arrangement of the circuit-closing system.

Mode of action of apparatus.

Circuit breaking connections.

A spare lever E is provided with each box, to enable the apparatus to be used on the alternative arrangement called the Circuit Breaking system. In this case, the action of the armature being reversed, the catch at the end of the lever is made with a crook, so that when the armature ceases to be attracted by the action of a current, (which is always circulating when the apparatus is in its normal condition), it will be drawn back by the force of the spiral spring, and the lever will be released. This arrangement is not so stable as the circuit closing system; with the former, upon any cessation of the circulation of the current caused by a jar, if the contact between the crooked end of the lever and the catch be momentarily broken, the armature will fly back, and the lever will fall. In the circuit closing system, the armature has no tendency to move till it is attracted by a current, and if, in this instance, the

contact between the end of the lever and the catch is momentarily disturbed by a concussion, the lever would not be released thereby. The circuit breaker lever can be readily substituted for the other by unscrewing the brass knee supporting the pivot of the lever.

Electrical circuits of apparatus.

The different circuits which have now been described, are the Shutter circuit, the Test circuit, the Observing circuit, and the Firing circuit. Switch pin holes are provided, in the plate on the top of the box and in the shutter battery plate in the front of the box. By the use of these the circuit of the apparatus itself can be readily examined. The resistance of the coils of the electro-magnet is 18 ohms. By means of the adjusting screw and spiral spring, the armature can be so adjusted, that with a given battery force, (say 2 cells of Leclanché), and a given resistance of about 60 units, the armature will be just attracted, when the battery current is completed, on short circuit. This adjustment of the armature should be daily examined. In the shutter signalling apparatus of this form, which has now been for several months under experiment, in connection with a series of mines at the Nore, the spiral springs, which are made of German silver, remain fairly constant. The intervals between the horns of the cores and the armature, can be adjusted by means of the screws *q*, *q*, at the front extremities of the cores. The intervals at the upper and lower horns should be made exactly equal.

Adjustment of sensitiveness of instrument.

Box containing apparatus.

The whole apparatus has been very conveniently arranged in a box, with a front projecting ledge, as shewn in *Plate* LXXIX. It is 36 inches long, 8½ inches broad, including the ledge, 10 inches high and is supported on four india-rubber feet, to save the apparatus from concussion by a blow on the table, or from that caused by the firing of heavy guns in its immediate vicinity. The firing connections, in the front of the box, are provided with a wooden cover, to prevent any accidental completion of the firing circuit. A separate shutter terminal A is provided for each index, so that, if necessary, each mine may have its own shutter battery. When the insulation of the mines is good, and the resistance of their circuits nearly equal, it will be found a simple arrangement to provide one shutter battery for each set of mines, connecting all the terminals by a piece of insulated wire running along the front, with the conductor exposed at the places A, A, A, where each binding screw bears upon it. For this purpose the battery should be arranged with 2 cells in series and 7 cells side by side, making 14 cells in all. Should any circuit become faulty, it would be necessary to detach it from the others, and provide 2 cells, on its own shutter terminal, for the exclusive use of that particular circuit. All the positive poles of the shutter batteries may be connected together and attached to the same earth connection. A preferable arrangement for this combination, would be to provide 2 cells of large surface, to corres-

pond with the 7 here described, and thus to get rid of the complications arising from the conection of smaller cells in this way, which has been found to be objectionable.

The front of the box, containing the electro-magnets, is movable and provided with a hinge at the top, so that it may be turned back to admit of easy access to the several shutters, &c. Openings, filled with glass, are arranged opposite each shutter, so that its condition may be inspected without opening the front.

Combination of shutter signalling apparatus with firing arcs.

The connections of the firing arcs, when used in combination with the shutter signalling apparatus, are all made through the series of binding screws, F, F, F, *Plate* LXXIX., on the top of the box. After a careful examination of the connections, it may be easily understood how the self-acting method of firing and that through the firing arc or firing keys, by intersection, may be arranged without interfering one with the other. The firing circuit is the same for both, while the signalling circuits for the self-acting system and method of firing by intersection are entirely separate and distinct: each however connected with the same object in view, namely, to close the circuit through the coils of the electro-magnet and drop the shutter. These connections, as far as the method of intersections is concerned, may be easily understood by reference to *Plate* LXV., *Fig.* 1. Under such circumstances, the connections might be as follows: at station *b*, each of the binding screws F, F, F, *Plate* LXXIX., should be connected to a corresponding terminal on the front of the firing arc; the rear binding screw, on the vertical arm supporting the telescope of the firing arc, should be connected to one terminal of the single firing key, while the other terminal should be attached to the insulated core of the electric cable connecting the two stations, and so on through the firing key at station *a* to earth. In this way it is easily seen, how the circuit, through the coils of the electro-magnet, will be closed by the simultaneous depression of the keys at both stations. This done, the armature would be attracted, the shutter dropped, and the mine fired. In any other combinations, such as those already described in pages 224 and 225, in which this apparatus may be introduced, the same general principles hold good, and only differ in details, dependent on the arrangement of the firing keys and firing arcs, required for the conditions of each.

Woolwich testing and firing table.

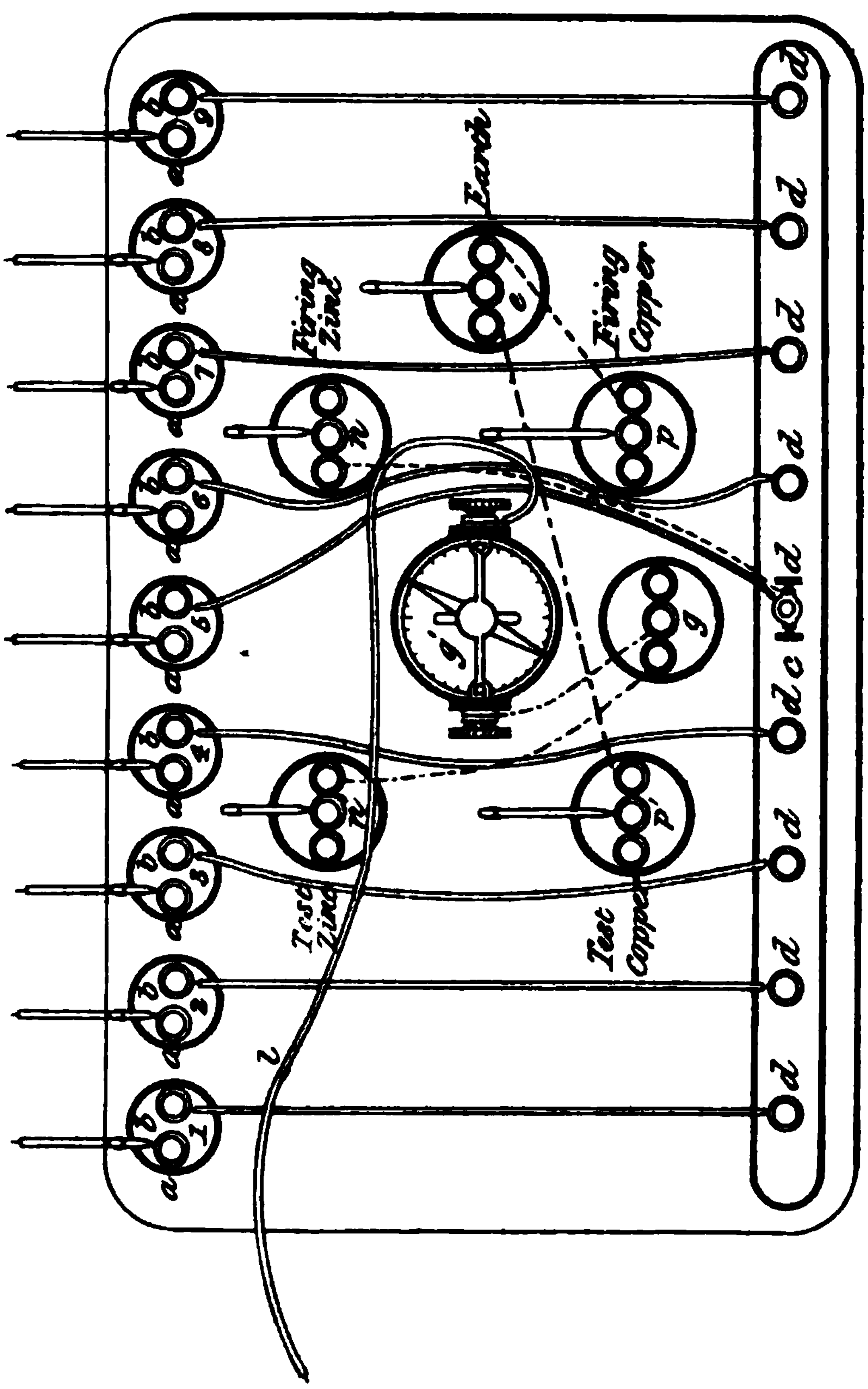
A form of testing and firing table, adapted for a self-acting system of mines, the general arrangement of which is shewn in *Plate* LXXX., has been designed in the Chemical Department, Woolwich. This was one of the first of the sort devised, and a modification of it has since been adopted by the Torpedo Committee for Submarine Mining Service. The electric cables in connection with the mines, having been brought into the fort,

are each attached to a series of screw plugs, inserted into perforated metal plates insulated by ebonite rings, *a*, *a*, *a*, *&c.*, which latter are numbered to correspond with the number of the mine, or system of mines, to which each belongs. A second series of screw plugs, *b*, *b*, *b*, *&c.*, in metallic connection with *a*, *a*, *a*, *&c.*, is arranged to receive a series of insulated wires, connecting the electric cables with a metal plate *c*, by means of a series of binding screws *d*, *d*, *d*, *&c.* This metal plate *c* is permanently connected with the firing battery; if therefore a vessel were to strike one of the circuit closers of the system, the circuit of the firing battery would be completed, through the fuze, and the fuze would be fired. The positive, (copper or carbon), pole of the firing battery is connected with the plate *p*, containing three holes for screw plugs, which are brought into metallic connection by it: the negative, (zinc), pole of the battery is connected with a similar plate *n*. Another insulated plate, *e*, made to receive three plugs, the centre one of which is connected to earth, is placed in a convenient position on the table, to facilitate such changes of connection as may be required in using the apparatus: three holes are supplied in each case, so that one or more connections may be made at each of the points *p*, *n* and *e*, if required, as it may be necessary to use more than one such connection at a time in testing the condition of the lines. When arranged for action, the positive pole *p* of the firing battery is connected to *e*, and the negative *n* to the plate *c*, as shewn by the dotted lines. The positive, (copper), pole of the testing battery is connected, by means of a screw plug, with the plate *p′* and the negative, (zinc), pole with the plate *n′*, two other screw plugs in each case being, as before, disposable for any required connections. Another insulated plate, *g*, is in connection with one binding screw of an astatic galvanometer, *g′*, placed in a convenient position on the table, while an insulated wire, *l*, long enough to reach to any one of the screw plugs of the combination, is attached to the other terminal of the galvanometer. The positive pole *p′* of the testing battery is permanently connected for work with one of earth terminals at *e*, while the negative pole *n′* is connected with one of the terminals at *g*. The whole object of these numerous binding screws, is to give facility for changing the several circuits with the least possible delay.

Use in testing.

In order to test any one of the electric cables for insulation, conductivity, or for any other purpose, it would only be necessary to disconnect it, for the time, from the firing circuit, by removing the connection between the screw plug *b* and the plate *c*, and to insert in its place the wire *l*; the testing battery would thus be put in circuit, through the galvanometer, with the particular line to be operated upon, and its efficiency as regards insulation, conductivity, etc., indicated by the movement of the needle of the instrument.

WOOLWICH TESTING AND FIRING TABLE.



Lithographed at the S.M.E., Chatham. B. Butler, Corpl. R.E.

To test the condition of the firing battery, Mr. Abel, originally designed a small set of resistance coils, for use in connection with a thermo-galvanometer or bridge, in which he proposed to place a definite short length of fine platinum wire of known electrical resistance. The working power of the battery would be tested, by the fusion of the thin platinum wire through a given electrical resistance, as indicated by resistance coils put in circuit, and a practical test of its efficiency would thus be obtained with great facility. This test would of course only be applicable, in the case of a battery possessing the power to fuse a fine platinum wire; and it would be necessary actually to fuse, and not simply to heat the wire more or less red, in order to obtain definite knowledge concerning the battery, as previous to actual fusion, no definite information, as to the degree of heat produced by the battery, could be obtained by this means, as a measure of its working powers. This arrangement has been adopted and combined in the approved form of testing table: its practical use, in testing the present form of firing battery, having been very satisfactorily confirmed. To test a battery which would not fuse a short length of fine platinum wire, some other means must be adopted, as for example by noting the swing of a heavy needle, given by the battery current on a galvanometer of low resistance, but the same kind of information might be obtained by firing any form of tension fuze, of known resistance, and through a known resistance as indicated by the resistance coils. The battery power required to fire a tension fuze, would not perhaps be determined within such small limits as that necessary to fuze the platinum wire, but it would answer perfectly well for practical purposes. Whether the platinum or tension fuze were employed, it would not do to rely on the results of such an experiment, to determine absolutely the number of battery cells to be used in practice. If a certain number of cells, tried in this way, just fired the fuze through a resistance equivalent to that of the electric cable, etc., it would be desirable in practice to double that number of cells. It must be remembered, that the conditions in the experiment are always far more perfect, as regards insulation, etc., than can ever occur in practice, where all sorts of deteriorating influences must necessarily exist to mar, at least in a degree, the perfection of the combination.

Arrangement for testing firing battery.

The resistance coils and connections for these tests must be suited to the nature of the firing battery used, for example, thick wires in the resistance coils if a battery of large quantity is employed, and fine for a battery of small quantity. The whole may be arranged in any convenient position on the testing table.

Wire of coils must be suited to battery current.

It was also proposed to provide the testing table with a commutator, by which means the number of battery cells used for testing purposes could be rapidly and conveniently altered.

Commutator.

This has also been adopted in the service form of testing table.

Form of testing table adopted for service.

The form and general arrangement of the testing table adopted for service, is shewn in *Plate* LXXXI.. It consists of a deal board about 1in. thick, size 3ft. 6in. by 2ft. 8in., or sufficiently near to these dimensions to suit any particular space available in the testing room, and supported on short legs about 4 inches high. In the centre is placed the astatic galvanometer, permanently connected to two switch plates A and B. Arranged in a semi-circle, beyond the astatic galvanometer, is a series of switch plates C, G, H_1, H_2, H_3, &c., used for the connection of any particular line to be tested, as well as for the earth connections and instruments employed in that operation:—these are let in flush with the surface of the table, and secured by screws to keep them in position. The arrangement shewn, is that required when certain earth plates are kept in a bucket, as proposed by Mr. Brown, and if this method were not employed, the only difference would be that these connections would be carried direct into the sea.

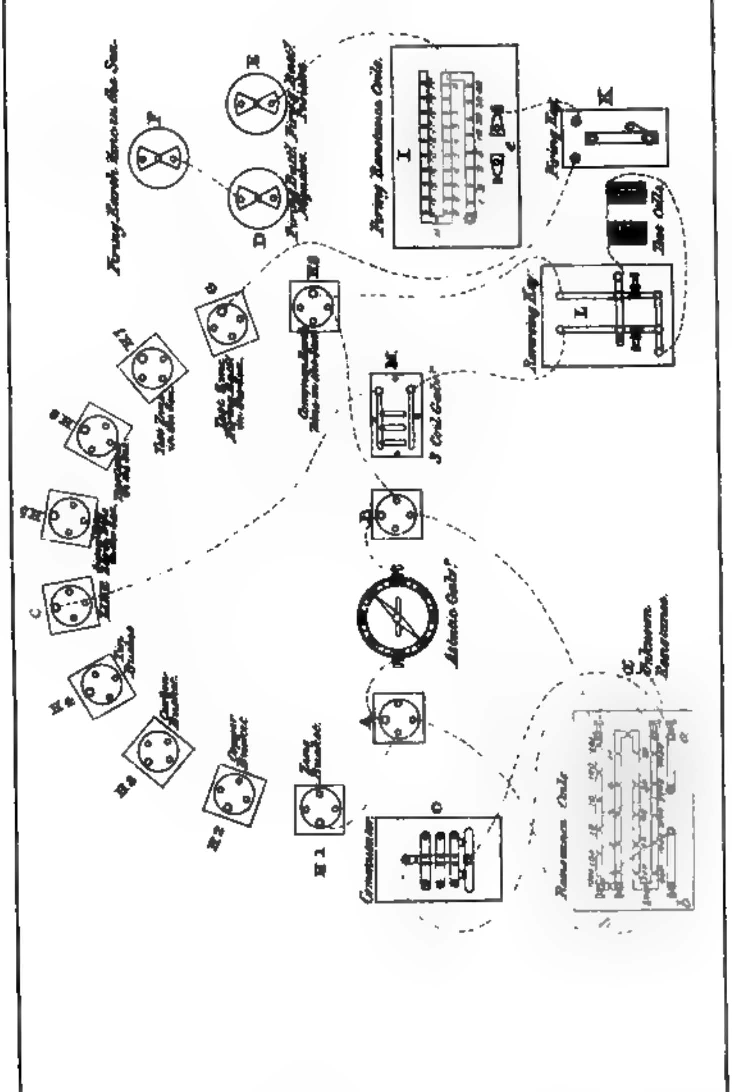
Connection of switch plates.

The switch plate C is used for the connection of any particular cable of the group, which it may be desired to test. The switch plate G is connected with a zinc earth plate, used for testing the firing battery: *this must always be in the sea.* H_1 is in connection with a zinc earth plate, in the bucket containing the testing earth plates: H_2 attached to a copper earth plate in the bucket: H_3 attached to a carbon earth plate in the bucket; and H_4 to a tin earth plate in the bucket. H_5 is used for connection with the zinc, signalling earth connection, *in the sea*: H_6 is in connection with a copper earth plate, used for the sea cell test, or any purpose required, *in the sea*; H_7 is attached to a zinc earth plate, used for the sea cell test, &c., *in the sea*; and H_8 is a common zinc earth, *in the sea*. The construction of all these switch plates is the same; they consist of a square ebonite plate, into the centre of which a circular brass plate is inserted, flush with the face of the ebonite: this brass plate is completely insulated by the ebonite, which latter is thicker than the brass and thus completely covers it on all sides; it is provided with a brass binding screw and four plug holes, through any one of which a metallic circuit may be established, by the simple insertion of a brass plug. Screw holes are provided, through the ebonite plates, to enable it to be firmly attached to the table.

Testing connections of firing battery.

D and E are plates used for the connection, for testing purposes, of the negative and positive poles of the firing battery, and F is a zinc earth plate for a similar purpose, *in the sea*. These plates are used in connection with the resistance coils employed for testing the firing battery, by means of the thermo galvanometer *e*, the circuit being completed by the firing key. The plates D, E, and F are all similar in construction, and consist of a circular ebonite plate, arranged to be let in flush with

SERVICE TESTING TABLE.



Lithographed at the S.M.E. Chatham. B. Butler. Corpl R.E.

the surface of the wooden testing table, and with two brass pieces each provided with a binding screw, and insulated from the other, but capable of being put in metallic connection by the insertion of a plug where they nearly touch.

Resistance coils for testing firing battery.

The resistance coils, used for testing the firing battery, are composed of wire adapted for the passage of a quantity current: any resistance from ·05 to 100 ohms, may be introduced. The thermo-galvanometer *e* is fitted to hold $\frac{3}{10}$ in. of thin platinum wire in the circuit, and the fusion of this wire, through any given resistance, constitutes the test to which the battery is subjected. The firing key K is of the form shewn in *Plate* LXVII., *Fig.* 4.

Connections of 3-coil galvanometer and reversing key.

L is a reversing key, in connection with a small testing battery, (two Daniell's cells), and the 3-coil galvanometer M. It is constructed on the same principle as the keys of a single needle instrument, and consists of two bridges, completely insulated from each other, the upper one attached to the negative and the lower to the positive pole of the battery. In their normal position, both the keys remain in contact with the upper plate and no current can circulate till one of them is depressed. The point of each key is provided with a binding screw, one of these is connected to the earth plate H_8 and the other to one terminal of the 3-coil galvanometer, when the tests are to be applied. The 3-coil galvanometer M is provided with a vertical needle, like that of an ordinary detector. It is formed with 3 coils, of 2, 10, and 1000 ohms resistance: the whole is arranged in a compact form and enclosed in a mahogany case. Each coil is connected with a brass plate on the top of the case, and may be switched into circuit by means of a plug, at will. The object of the three resistances of 1000, 10, and 2 ohms, is to suit the different resistances which may occur, with a perfect or imperfect state of the electrical combination in connection with each mine.

Construction of 3-coil galvanometer.

Resistance coils and Wheatstone's bridge.

A set of resistance coils, from 1 up to 11,110 ohms, in connection with a Wheatstone's bridge, is arranged on the testing table at N. This apparatus is of the Post Office pattern, and is used in finding the resistances of electric cables, before or after submergence, balancing fuzes, or any other similar work. Its chief difference as compared with ordinary instruments, consists in the introduction of a couple of keys, shewn in *Plate* LXXXI., in connection with the terminals *a* and *b*, by the depresssion of which the circuit is completed. The advantage gained by this construction is the exclusion, in a convenient manner, of the battery, till the plugs and connections, required for any given tests, have been arranged. The instrument may be thrown in circuit with the the astatic galvanometer when required, by means of plugs inserted in the switch plates A and B.

Commutator

A commutator is provided on the testing table, at the point O. This is employed in connection with the testing batteries used with the Wheatstone's bridge, &c.: by it the necessary number of cells, for any particular test, may be thrown into circuit when required.

CHAPTER XIII.

Mechanical and Electrical Tests.

The tests applied to the component parts of a system of submarine mines, are of two kinds, mechanical and electrical. The former to ascertain that the strength and mechanical working powers of the apparatus employed, are such as to ensure their efficiency:—the latter to ascertain that the electrical conditions necessary to a successful result exist.

Tests of Instruments. As a preliminary to all electrical testing, it is necessary to ascertain that the instruments, batteries, etc., used in making the tests, are themselves in good working order; otherwise defects which exist in the testing instruments, may produce results, which might be mistaken for defects in the apparatus under trial; for example, a want of proper connection in the construction of a galvanometer, might be mistaken for a want of conductivity in an electric cable, or for a high condition of insulation, which might not exist.

The following modes of testing the several component parts of the system may be adopted:—

Tests of explosives. The explosive used would be either gunpowder, gun-cotton, or some similar compound; as a general rule these might be accepted as of good quality, but should any suspicious appearances present themselves, or should facilities be at hand, tests should be made. Gunpowder may be tested by an eprouvette, or by firing small charges out of a mortar and measuring the range obtained. Guncotton may be tested chemically, or practically, in the latter case to ascertain that it possesses detonating qualities. Any other explosive of a similar nature could be tested in a similar manner.

Tests of case. The case to contain the charge, should be tested to ascertain that it is thoroughly water-tight, and capable of bearing external pressure to the extent required, according to the depth at which it is to be submerged. This test may be applied by forcing in water, by means of a hydraulic press, to any given pressure, and observing the joints, etc., to see that nothing comes through them or through the body of the plates themselves. This should be done during the process of manufacture, and the leaks at the joints, should any exist, should then and there be caulked. Any leak through the body of the metal itself would necessitate the rejection of the entire case.

Cases of $\frac{1}{2}$-in. boiler-plate iron should bear a pressure from within, of 75lbs. on the square inch, without a suspicion of leak: cases of $\frac{1}{4}$-in. boiler-plate should be similarly tested to a pressure of 40lbs., and cases of $\frac{3}{16}$-in. to a pressure of 30lbs. on the square inch, gradually increasing from within. The 100lb. cases, of the construction described in page 52, should be tested to a pressure of 15lbs. to the square inch, gradually increasing from within. To test for capacity to bear external pressure, the cases, having first been made complete with mouthpiece, &c., to close the loading hole, as for service, as described at page 154, should be submerged to a depth somewhat exceeding that at which they are eventually to be used. After remaining thus submerged for not less than 48 hours, they should be lifted, opened, and carefully examined to see that they remain perfectly dry inside. In making this examination it would be necessary, in the event of damp having penetrated, to ascertain whether it had forced its way in at the junction of the mouthpiece, or through the joints or metal plates composing the body of the case. No electrical test can be applied as far as the simple metal is concerned; when complete, however, with mouthpiece, fuze, &c., before submersion, an electrical test, to be hereafter described, should be applied to ascertain the condition of the apparatus as a whole.

Tests of mooring apparatus.

All mooring apparatus should be tested mechanically. 1st, to ascertain that the weights of anchors or sinkers are such, considering the buoyancy of the case, rate of current in which it is to be moored, and nature of bottom or holding ground, as to keep the mine in its proper position after submersion. 2nd, the chains, wire cables, and ropes to be employed, should be examined to see that they are of sound construction; and if the slightest doubt exists as to their quality, they should be further tested mechanically, by applying a strain of a measurable nature, to ascertain whether they are fit to perform the work required. Tests of this nature are always employed before such articles are received into the service, and they are chiefly necessary, as here recommended, to ascertain that no deterioration has taken place while in store: hemp rope, for example, might in time become rotten. No electrical tests are applicable to this part of the apparatus.

Tests of mechanical fuzes.

Mechanical fuzes, such as the sulphuric acid fuze, &c., might often be improvised, and should be practically tested in course of construction. A fuze of this nature which may at any future time be made an article of store, to be drawn out as required for use, must be tested practically, by selecting a certain per-centage, of those issued and firing them; should the results be good the whole may be accepted as of good quality, if failures to fire occurred they would indicate more or less deterioration or imperfection in the whole. Abel's Torpedo Primers should be tested in this way. Mechanical fuzes cannot be tested electrically.

Tests of

The platinum wire fuze may be very simply tested electrically.

platinum wire fuze for conductivity. If placed in circuit with a few cells of a battery *c z*, and a common detector galvanometer *g* as shewn in *Plate* LXXXII., *Fig.* 1, before the fine platinum wire *p* is soldered across between the wire points, there should be no deflection of the needle, for no metallic circuit should exist; if it did it would be fatal to the efficiency of the fuze. If placed in circuit with the same battery and galvanometer, after the fine platinum wire had been connected to the extremities of the larger wire points, a considerable deflection of the needle should result, such deflection being due to the current passing through the platinum wire bridge, which to be efficient ought to be the sole medium through which the circuit is completed. This test should be made with a few cells of Daniell's, telegraph pattern, or other similarly constituted battery, the current generated by this form of battery being of such a nature, that no sensible heat would be produced in the platinum wire, and no chance of an explosion of the fuze incurred. This is especially necessary in testing the fuze after it has been placed in the charge, when a premature explosion would, of course, be a very serious matter. The current of Grove's, or other battery, so constituted as to fire a platinum fuze, might moreover, injure, if not destroy, the coils of the galvanometer, if passed through them on short circuit, unless specially constructed for use with it, and should never be thus employed. The continuity of a platinum wire fuze may also be tested, by means of a water decomposer, as shewn in *Plate* LXXXII., *Fig.* 2. The passage of the electric current through the water would decompose it, and hydrogen bubbles would be deposited on the point in connection with the negative pole of the battery. Should a want of continuity exist in the fuze, no current would pass and no water would be decomposed. The apparatus consists simply of a glass bottle *a* to contain the liquid, into which a pair of wires *b*, *b*, insulated from each other, have been introduced, by simply passing them through a cork. A single cell of Grove's, or any battery by which a platinum wire may be fuzed, may be used in testing for continuity with this apparatus, provided the insulation between the wires passing into the bottle is sufficiently good, and the space between them, within the bottle, is sufficiently great to obviate the chance of premature explosion. In testing with a Grove's cell, extreme care is necessary to prevent the accidental closing of the circuit, directly through the fuze, by bringing the terminals in contact with each other, without the intervention of the resistance of the liquid in the bottle; in order to guard against this, the wire terminals, outside the bottle, should be bent well apart. Salt, or acidulated, water is better than fresh for testing purposes, as exhibiting the effects of its decomposition more rapidly.

Test of resistance of The electrical resistance of a platinum wire fuze may be ascertained by balancing, by means of the set of resistance coils

PLATE LXXXII.

ELECTRICAL TESTING ARRANGEMENTS.

Fig. 1.

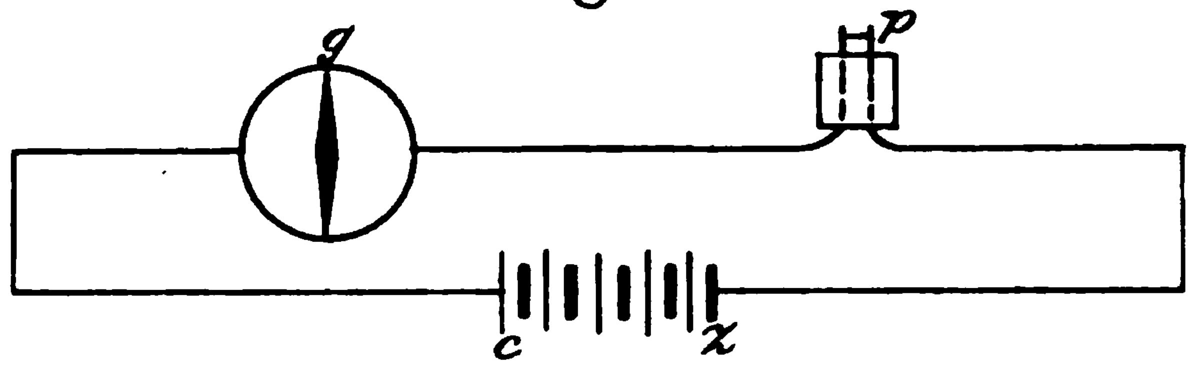


Fig. 2.

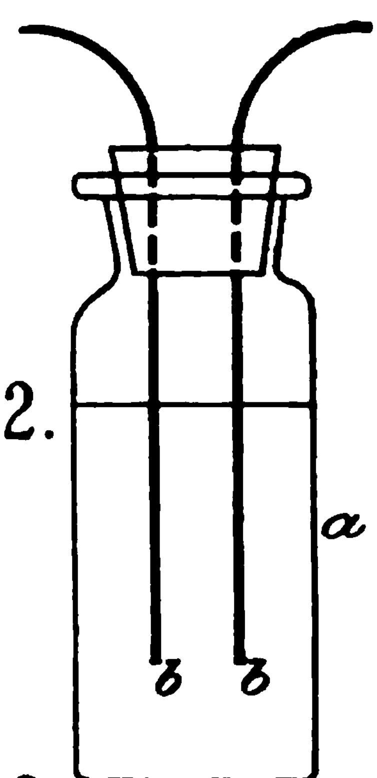
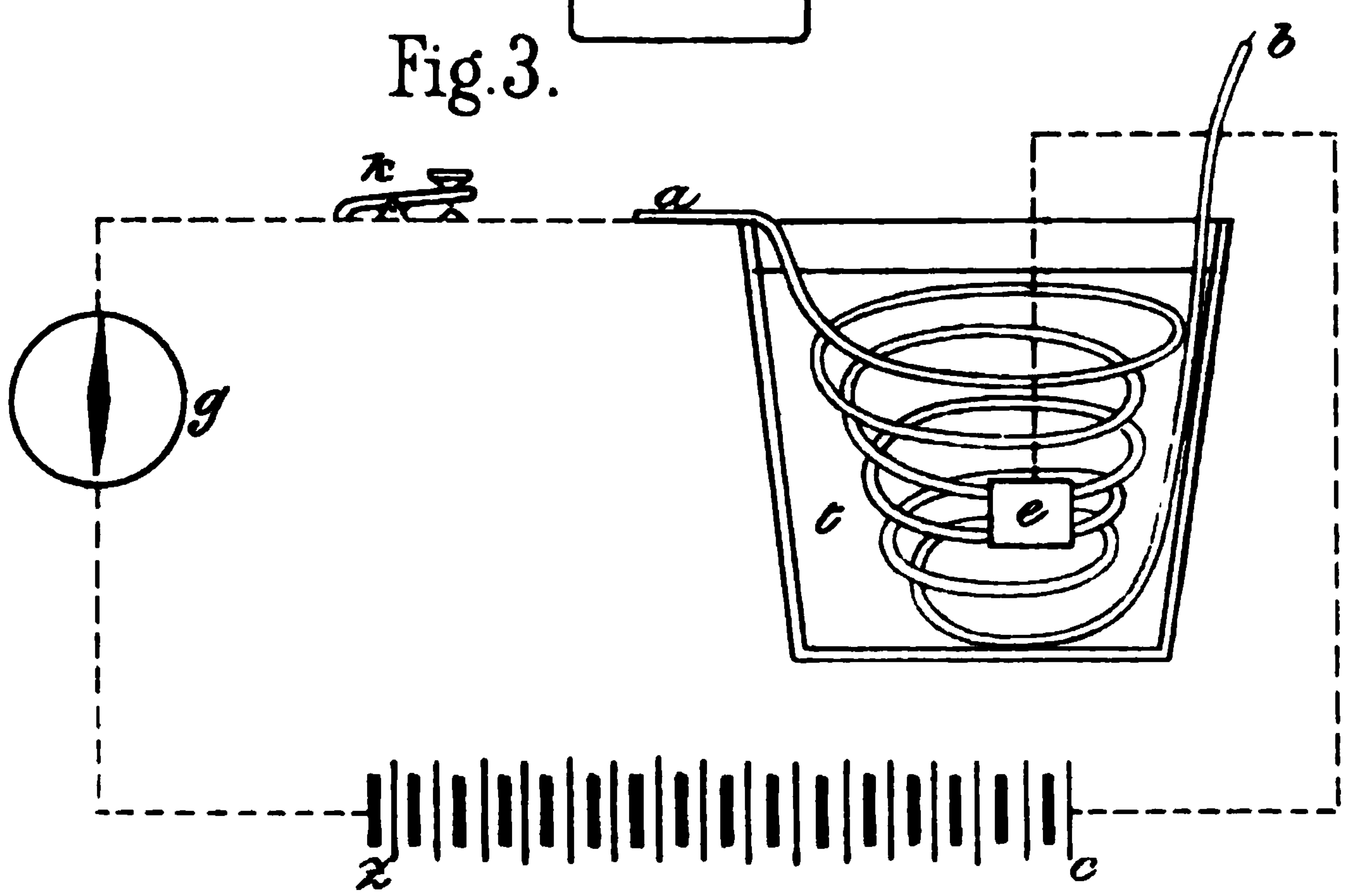


Fig. 3.



Lithographed at the S. M. E., Chatham. *B. Butler, Corpl. R.E.*

and Wheatstone's Bridge N, *Plate* LXXXI. Any number of Daniell's cells required to make the instruments work efficiently, may be used for this operation, but for the reasons already given, Grove's battery is inadmissable for such a purpose. To make the test, the fuze is connected between the terminals *c* and *d*, a sufficient number of battery cells are thrown into circuit, by means of the commutator O, and the terminals *b* and *c* are connected to the astatic galvanometer, through the switch plates A and B. The resistances in the proportional coils of the bridge, are arranged to enable the small resistance of the fuze to be balanced, and the resistance of the coils is adjusted, by taking out plugs, till the needle of the galvanometer is brought to zero, when the sum of the resistance, indicated by the unplugged coils, will give the number from which that of the fuze may be determined, according to the proportion of the resistances in circuit in the coils of the bridge. The electrical resistance of $\frac{3}{10}$in. of fine platinum wire, weighing 1·9 grs. to the yard, is $\frac{3}{10}$ of an ohm nearly, (Schaw); this is its resistance at the moment of fusion. The resistance of $\frac{3}{10}$in. of this wire, obtained by balancing with a set of resistance coils, is about of $\frac{2}{10}$ an ohm. The bridges of the platinum wire fuzes and detonators, manufactured in the Royal Arsenal, are formed of a thinner platinum wire than that employed, in his experiments, by Colonel Schaw: this wire weighs about 1·6 grs. to the yard, and the resistance of the fuze is thereby increased to an average ranging from $\frac{1}{4}$ to $\frac{1}{2}$ an ohm. Fuzes with resistances within these limits, may be accepted as fit for service. The resistance of a platinum wire fuze, might be ascertained by means of a differential galvanometer instead of Wheatstone's bridge. The latter, however, is more accurate and has been adopted for service in the very compact form shewn at N. *Plate* LXXXI.

platinum wire fuze.

Tests of high tension fuzes for conductivity.

Fuzes adapted to be fired by electricity of high tension, require much more careful and delicate management in order to test them; they may, however, be tested for conductivity and resistance, and this must always be done before they are used in any operations connected with submarine mines, to ensure the maximum of efficiency at the proper moment. The test for conductivity must be made with a few Daniell's, or other similar battery cells of small surface, adapted for tests of this nature, and an astatic galvanometer. The high electrical resistance of fuzes of this description, amounting in the case of the service fuze, (No. 6 detonator, electric, Abel, submarine) to as much as 15000 ohms, combined with the danger of premature explosion when testing, even with a comparatively small number of battery cells, renders it necessary to employ the astatic galvanometer, on which, in consequence of its greatly superior sensitiveness, a deflection is produced by a comparatively small current. A reflecting galvanometer would of course be preferable for such work, but it is much more expensive and not a very portable instrument, and the astatic galvanometer has been found, in practice, to be sufficiently sensitive.

Tests of resistance of high tension fuzes.

The resistance of the service tension fuze may be obtained by balancing, by means of a set of resistance coils and Wheatstone's bridge, in connection with the astatic galvanometer, as in the case of the platinum wire fuze. For the reasons already given, a very moderate battery power must be employed in this operation. The precautions necessary in testing Abel's fuzes are given at pages 101 to 104, and these must be adopted generally in testing high tension fuzes of any form. They should be connected to the Wheatstone's bridge in precisely the same manner as that described for the platinum wire fuze, the proportional coils being, however, arranged in this case so that the larger current may pass through the resistance coils and the smaller through the fuze. The battery used in this combination, for testing purposes, should be 2 Daniell's cells. For work, fuzes of about 15000 ohms resistance should be selected. A reflecting galvanometer would, for the reasons already given, be preferable to the astatic for use in this test: the latter has, however, been found to answer the purpose very well, and, being a much more portable instrument, has been adopted for service.

Tests of detonating fuzes

The tests to be employed for detonating fuzes are precisely similar to those for ordinary fuzes of the same construction, the only difference being in the priming, (fulminate of mercury instead of gunpowder). They should, however, be subjected to a further test to ascertain that their detonating properties are sufficient to ensure success; a deficiency of detonating composition will often produce imperfect detonation in the explosive itself, when used with compressed gun-cotton. A per-centage should, therefore, be tried to ascertain their efficiency in this respect.

Each fuze should be tested before and after it is placed in the charge, subsequently as a part of the general combination in which it is to be submerged, and finally, directly it has been placed in position for work. Any change in the results obtained by the first and subsequent tests applied, would indicate a change in the electrical conditions, as well as give such information as would indicate the efficiency or otherwise of the system, as will be hereafter explained.

Tests of electric cables.

Mechanical tests.

It is, perhaps, almost unnecessary to test electric cables, suitable for submarine mining purposes, mechanically for tensile strength; extraordinary precautions are taken, by giving them strong outer protecting coverings of iron wire, hemp, &c., intended not only to give tensile strength, but to protect them from injury by rubbing against rocks, &c. Special precautions too are employed to prevent any great strain being brought to bear upon them, either during or subsequent to submersion. Should, however, any doubt arise, as to the ability of a cable to sustain a strain likely to be put upon it, it may be tested for tensile strength in the same manner as an ordinary rope. When an improvised electric cable is employed, it would always be neces-

sary to ascertain its tensile strength before putting it to practical use.

Insulation test for electric cables.

Electric cables should be tested electrically for insulation, conductivity, and electrical resistance. To test for insulation the cable should be put in a tank of water and allowed to soak for 48 hours. The object of this soaking is to allow the water to penetrate through the outer protecting covering of hemp and iron wires, and to search out and get into any weak places there may be in the insulation. After soaking, one end *a* of it should be connected, as shewn in *Plate* LXXXII., *Fig.* 3, with an astatic galvanometer *g*, and battery *c z*, of not less than 100 Daniell's cells, while the other end *b* should be carefully insulated. The battery circuit should be completed by an earth plate *e* in the tank *t*, through the galvanometer *g* and the deflection of the latter should be observed. It is manifest that in such a combination any current, passing through and deflecting the galvanometer, could only complete the circuit by passing through the insulation of the cable. A very slight deflection would frequently be observed on a moderately sensitive galvanometer, in such a combination as that indicated in the figure, even with a well insulated cable. This would be due to the current passing through the insulation, its whole length being immersed, the surface, through which such a current would pass would be large, and the sum of the infinitesimally small quantities, escaping over the whole length, would in the aggregate be sufficient to deflect the galvanometer to a small extent, in completing the circuit of the battery. Should any considerable deflection occur it would indicate a defect, or leak, in the insulation of the cable, the extent of which would be roughly measured by the amount of such deflection. In making a test of this nature, a large number of battery cells, at least 100, should be used, the object being to obtain high electro-motive force, to drive the current through any defects which may exist. The battery current should not be kept circulating longer than necessary during a test of this nature, and in order to close and break the circuit with facility, it would be convenient to insert a key *k* of the form shewn in *Plate* LXVII., *Fig.* 4, in the combination. Should a leak exist in the cable, the effect of the continuous passage of a current of electricity would be likely to injure the cable, for well-known reasons. If the tank, in which the cable was coiled away, were of iron or other metal, the earth plate *e* might be dispensed with, and the circuit simply connected by a wire to the tank itself. When no tank is available an electric cable may, for testing purposes, be immersed in the sea, or in any water, and equally good information obtained by testing it in the manner described. Electric cables are always most carefully tested during the process of manufacture, and would subsequently be tested before being passed for service. They should, in addition to this, be tested periodically wherever they may be kept in

store, to ascertain that they remain in good condition, as well as immediately before they are connected up for work.

Test of electric cables for conductivity.

Having completed the test for insulation, an electric cable should next be tested for conductivity. To do this it would only be necessary to remove the insulation from the end *b*, *Plate* LXXXII., *Fig.* 3, of the cable, so as to expose the metallic conductor, and put it in the water of the tank. If the conductivity were good, the whole of the battery current would then pass through the cable, and the galvanometer would be violently deflected. If the continuity were broken, no deflection of the galvanometer would occur. In making this test, the battery power should be reduced to 2 cells.

Very much more delicate tests for insulation might be obtained, by substituting a reflecting for an astatic galvanometer, and this form of instrument is always used by the manufacturers; but for the comparatively short lengths of electric cable, required for use in submarine mining operations, such minute accuracy is seldom necessary, though, at important stations, the more delicate apparatus might be very usefully employed.

Sensitive galvanometers best for testing purposes.

It must be borne in mind, however, that whatever instrument is used, the deflection of a galvanometer only conveys a comparative idea of the current passing through its coils. A current which would produce absolutely no motion on an insensitive galvanometer, would cause a considerable deflection in the needle of even a moderately sensitive instrument. An operator should, therefore, know the nature of the instrument with which he is working, and it is preferable for him to employ a tolerably sensitive instrument, with the use of which he is thoroughly acquainted, than a rough one with which the more delicate observations could not be made. The sensitiveness of an instrument can be diminished at will, by means of shunts, or by a permanent magnet, arranged to act directly on the needle.

Negative current best for testing purposes.

The negative (zinc) pole of a battery should always be attached to a cable for testing purposes, because if the positive (copper) pole were attached, a salt of the metal of which the conductor was formed, would be immediately deposited in any defect which might exist in the insulation, if the metallic conductor were in the slightest degree exposed. This would occur in any water, unless absolutely free from impurities, and would be especially the case in salt water, in which a chloride of the metal would be quickly formed. This would almost immediately insulate the defect to a certain extent, and a true deflection would not be obtained on the galvanometer. The effect of a negative current would be to decompose any such salt and to deposit the metallic component on the conductor, and thus, so to speak, to clean the defect and expose a purely metallic surface at the point required.

Tests for multiple cables.

To test a multiple cable for insulation and conductivity, a similar course should be pursued with each conductor as has been

described for a single cable. In testing each single core, the conductors of all the others should be put to earth, to obviate the effect of induction which would more or less, according to the length of the cable, interfere with the results of the observations obtained. This is always necessary in testing long lengths of multiple cable, and even with the comparatively short lengths used for submarine mining purposes, it is a good precaution to observe.

To discover position of a defect of insulation.

Should a defect in insulation be indicated by the tests above described, its position might be readily ascertained, by keeping a continuous current on from the battery, and gradually taking the cable out of the tank. If the imperfection existed at a single point, the deflection of the galvanometer would be suddenly much reduced, at the moment the defect was raised out of the water, and its position would thus be determined with considerable accuracy. Should several defects exist, as each was lifted out a sudden reduction of deflection would occur. It must, however, be borne in mind, that after an electric cable has been for some time immersed under a pressure of water, the latter is forced into any openings, however minute, which may exist in the insulation, and in the case of a small defect it will remain and form a path for the current, between the conductor and the external armouring, and, consequently, an earth connection, even after the cable has been lifted out of the water.

Discharge test.

Want of continuity in an electric cable may co-exist with perfect insulation, for example the conductor might be parted within the insulation while the latter remained good. Under such circumstances, the tests above described would indicate good insulation but no conductivity, without giving any information as to the position of the severance of the conductor. To ascertain this, the following test may be applied :—Having put one pole of a battery of 200 or more Daniell's cells to earth, charge one end of the defective cable, and immediately discharge it through a reflecting galvanometer, noting the extreme limit of the swing of the needle; then charge the other end of the cable in a similar manner, and discharge it through the same galvanometer, noting the swing of the needle as before. This should be done three or four times, and an average of the deflections taken. The position of the break in the conductor, would be indicated by the proportion between the average deflections in each case, and the cable might safely be cut at the point so determined, which, if the tests were carefully made, would not be very far from the defect. Should the precise position of the fault not be discovered in thus cutting the cable, each section should then be again tested for conductivity, and that in which the fault was still found to exist should be again tested, by the discharge, as before. In this way the exact point would finally be discovered.

The deflection of the needle is dependent upon the quantity of current, at a given potential, discharged through the coils of the

galvanometer, and the quantity is, again, dependent on the electrical capacity of the conductor of the cable to contain a charge forced into it at a given potential, and its electrical capacity is directly in proportion to its length, supposing the conductor to be of uniform size throughout. The swing of the galvanometer needle measures the quantity of the charge, passed through its coils, in proportion to the sine of half the angle deflected (Jenkin); hence, on a reflecting galvanometer, the information would be given directly, in proportion to the number of divisions on the scale, as indicated by the extreme motion of the spot of light, while on a galvanometer reading the angular measure in degrees, &c., the sines of half the angles deflected would give the required proportion. Few galvanometers, except the reflecting instrument, are sufficiently sensitive to enable the "discharge test" to be employed.

Test of electrical resistance of cable.

After testing for insulation and conductivity, the electrical resistance of an insulated cable should be measured. This should be done by balancing it against a set of resistance coils, with the Wheatstone's Bridge, N, *Plate* LXXXI., and astatic galvanometer, in a similar manner to that described for the fuzes. The coils should be unplugged till the galvanometer needle is brought to zero, when the sum of the unplugged coils would be equal to the electrical resistance of the cable. The electrical resistance of the conductor of a cable, affords a very correct indication of the quality of the metal of which it is composed. Manufacturers always use a reflecting galvanometer in taking the resistance of electric cables; this is, of course, a more accurate method as the instrument is very much more sensitive. Where Wheatstone's Bridge is not obtainable, a differential galvanometer may, in this as in other cases, be substituted for it, the results obtained being, however, rougher, the instrument being less sensitive.

In making these tests, Daniell's, or some similar form of battery, should be employed, so that the delicate coils of the galvanometers, &c., may not be injured, as they might be if the current of a number of cells of Grove's, or any battery of similar nature, were passed through them.

Mechanical tests of water-tight joints.

Watertight joints and connections should be tested mechanically, by immersion, for not less than 48 hours, at depths somewhat greater than those at which they are eventually to be used, after which they should be raised, opened, and examined, to see that they remain dry.

Electrical tests of insulated joints.

Insulated joints and connections, whether of a permanent or a temporary nature, should be tested electrically, in a precisely similar manner to that described for electric cables. They should be soaked for 48 hours, and then tested for insulation, conductivity, and electrical resistance.

In testing the permanent joints made in a line of submarine electric cable, special precautions are taken, which are described by Mr. Culley as follows.

"A joint should insulate as well, or nearly as well, as an equal length of the perfect core, and the object of the test is to ascertain if this be the case. The leakage, even from a considerable length of good core, is too small to affect the galvanometer; although the electricity which escapes moment by moment cannot be measured, still if it were possible to store up the loss during a minute and compel it to pass instantaneously through the coils, it would produce a sensible deflection."

Delicate test of joints by special apparatus.

"In order to effect this, recourse is had to induction. A metallic trough, sufficiently large to contain two or three feet of the core, is suspended by straps or rods of polished ebonite, two or even three feet long. A small condenser is attached to increase its inductive capacity, and enable it to store up the electricity which may leak through the insulation. The testing battery, of not less that 200 cells, is insulated in a similar manner, and all loss over the surface of the conducting wires is prevented by paring their ends, so as to expose a fresh clean surface, or even by coating them with hot paraffin."

To test the apparatus.

"To ascertain if the apparatus is sufficiently insulated, the trough and condenser are charged, and the swing of the needle, from an immediate discharge, noted. They are then re-charged and left free for a time equal to that to be occupied by the test, and again discharged. The difference in the swing shews the loss in the time, and should be very small."

"The joint is placed in the trough, a negative current is applied to the cable, and the positive pole of the battery is connected to the outside coating of the condenser. Any leakage which may occur through the insulation is, by this arrangement, accumulated in the condenser, and may be discharged through the galvanometer, after any given interval."

"It is possible to find how much is lost by defective insulation during the joint test itself; but as both core and joint are subjected to the same conditions, and the object is simply to see if one insulates as well as the other, this precaution does not seem to be absolutely necessary."

Mode of making the test.

"To make the test. 1st. Place the joint in the trough—leave one end of the cable free;—connect the copper pole of the battery to the galvanometer; connect the other terminal of the galvanometer to the trough, and, finally, charge the cable by applying the zinc pole."

"The charge within the cable acts inductively upon the natural electricity of the trough, the wire being in fact the inner, and the water the outer, coating of a Leyden jar. A portion of the negative electricity of the water is set free, and an equal quantity of the positive is held fast or disguised by the negative charge within the cable. The free electricity is at once neutralized by the action of the battery; if it were not so arranged, it would increase the apparent leakage from the cable, being of a similar sign."

"The deflection or swing due to the discharge being instantaneous, it follows that if the needle *remains* deflected after the discharge, the joint is very bad, or there is leakage over the surface of the insulation. The latter may be conducted to earth so as not to interfere with the test, by wrapping an earth wire round the core a few feet from the free end."

"2nd. Without disturbing the charge of either cable or trough, connect one coating of the condenser to the trough, the other coating to the positive pole of the battery, the zinc being to the cable as before."

"Any negative electricity which may leak from the cable will now accumulate in the condenser. Allow one minute for this."

"3rd. Disconnect the condenser from the trough and battery, and discharge it through the galvanometer. If the trough and other parts of the apparatus have been well insulated, the swing will shew the accumulated leakage from the portion of core under test. It is evident that these changes must be made by perfectly insulated keys and commutators."

Effect of induction when several joints are simultaneously tested.

"It often occurs, when there are several wires in the cable, that the apparent leakage is greater from the joint which is first tested than from any of the other joints tested at the same time. This arises from the charge in the first wire acting upon the others inductively. The wires not under test should therefore be put to earth until they are wanted, and the condenser and trough should be perfectly discharged between each test."

"It will be understood that the results are simply comparative, not absolute; all that the method effects is to shew the difference between the insulation of a joint and that of any other part of the core."

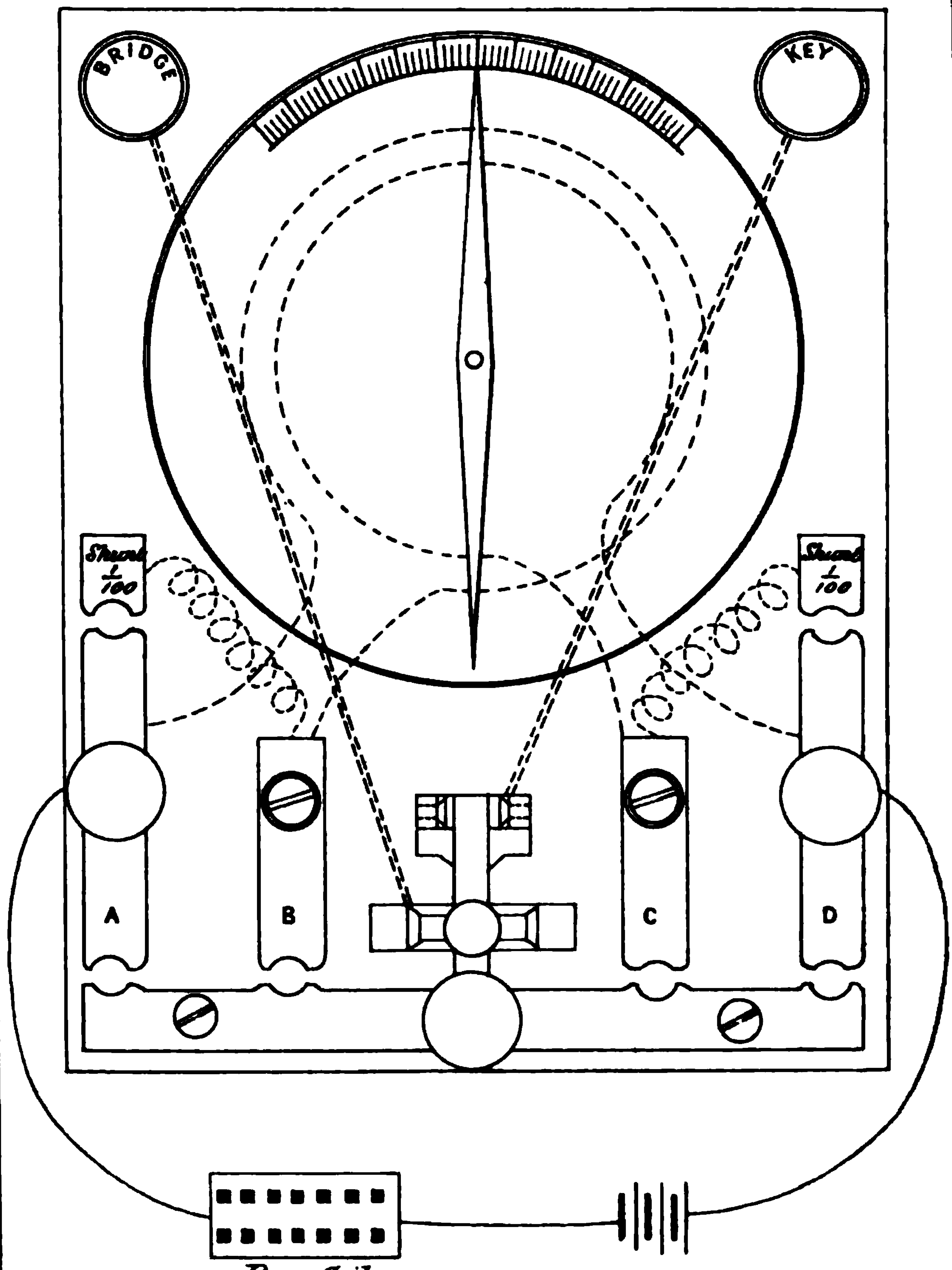
"This method somewhat differs from that ordinarily adopted. It is usual to put one pole of the battery to earth; but in this case leakage takes place over the whole cable, however long it may be. By the plan described, the leakage is confined to the part in the trough, the whole force of the battery is concentrated there, and the apparent leakage exaggerated."

Though such minute accuracy is not absolutely essential, in the short lengths of electric cable used for submarine mining purposes, it must be borne in mind that the higher the condition of insulation, the greater will be the efficiency of the system, and the longer the line, the greater the necessity for perfection, as far as it can possibly be attained. A cable with an insulation resistance of not less than 20,000 ohms per nautical mile, would answer perfectly for submarine mining service.

Tests of Wheatstone's Exploder, Frictional

All electrical instruments used for firing mines at will, such as Wheatstone's exploder, Siemens' dynamo-electrical machine, and the Austrian frictional machine, should be carefully examined and tested to see that their mechanical arrangements are in good working order. They should further be tested, with a fuse and

CLARK'S DOUBLE SHUNT, DIFFERENTIAL GALVANOMETER.



Lithographed at the S. M. E. Chatham. B. Butler, Corp^l. R. E.

known electrical resistence in circuit, to ascertain their power to fire that fuze with certainty. If the electrical resistance in circuit is considerably greater, (say double), than that through which they are required to work in practice, it may be assumed that they are in sufficiently good order to ensure success. The Austrian frictional machine has a special arrangement, by which its working condition may be ascertained, on short circuit, by the length of the spark passing across a given space on closing the circuit between the armatures of the condenser.

machine, and similar apparatus.

Tests of batteries.

Voltaic batteries should be tested for potential, internal resistance, and electro-motive force. The potential and electromotive force are proportional to each other; it is not, therefore, necessary to ascertain both. The method of testing the potential is, however, given, being generally interesting.

For potential.

The comparative potential of a battery may be very accurately determined by means of Thomson's Reflecting Electrometer; for this purpose, one pole of the battery should be put to earth, and the other to charge one pair of the quadrants of the electrometer; when this is done, a certain deflection of the spot of light will be observed, and the amount of deflection, as compared with that produced by a standard cell, applied to the instrument in a similar manner, would give the relative value of the potential of the battery. In making such observations it is necessary to take care that the condition of the electrometer, as regards charge in the Leyden jar, &c., is the same, while the deflections with the batteries under comparison are observed. The Reflecting Electrometer is not a portable instrument, and requires very careful and delicate arrangements in connection with it, and the beautifully minute and accurate information obtained by it is not absolutely essential to efficiency, in connection with the comparatively short lines of electric cable necessarily used for submarine mining purposes; its employment may therefore be limited to the more delicate observations necessary at important stations. It is much used by the manufacturers of electric cables, for their more delicate testing operations.

Test of internal resistance of battery.

The internal resistance of a battery may be readily obtained by means of a double shunt differential galvanometer and set of resistance coils, as recommended by Mr. Latimer Clark, in his book on electrical measurements, in the following manner.

Connections for the test.

Connect the battery and a set of resistance coils in circuit between the terminals A and D, *Plate* LXXXIII., and insert plugs in the resistance coils so that they give no resistance; insert plugs at A and C to connect the metal bar under the key, and also both the shunt plugs at A and D. The battery current will now flow through one half of the galvanometer circuit only, being however reduced to $\frac{1}{100}$th of its amount by the shunt D; the deflection of the needle must be carefully read. The plug A must now be removed to B, connecting this latter with the

bar under the key, and disconnecting A, which causes the battery current to flow through both halves of the galvanometer (each being shunted). Under these circumstances, the needle will, of course, be deflected somewhat more than before. Now unplug the resistance coils which are in circuit with the battery until the deflection of the needle is reduced to its original amount, and the resistances unplugged will be equal to the internal resistance of the battery. For example, assuming the resistance of the half coil to be ninety-nine ohms, and that of the shunt wire one ohm, the joint resistance of the two circuits will be:

$$\frac{\text{Galvanometer} \times \text{Shunt}}{\text{Galvanometer} + \text{Shunt}} \text{ or } \frac{99 \times 1}{99 + 1} = 0{\cdot}99 \text{ ohms.}$$

Suppose the resistance of the battery to be four ohms, the two together = 4·99 ohms, and the current acts on the galvanometer needle through one half of its circuit only: when the second half of the galvanometer is thrown into circuit, by shifting the plug from A to B, the resistance becomes $4{\cdot}99 + 0{\cdot}99 = 5{\cdot}98$, and therefore less current passes; but since it acts upon the needle through both coils instead of one, the deflection is greater than before. The resistance coils are now varied, until the needle recedes to its original deflection, which will necessitate the unplugging of a resistance of four ohms, making the total resistance now $5{\cdot}98 + 4 = 9{\cdot}98$, which is exactly double the first resistance; that is to say, in the one case we had the current acting upon one coil through 4·99 ohms, and in the other case acting upon the two coils through 9·98 ohms, the deflecting power on the needle having been increased in the same ratio as the resistance.

This measure is obtained in terms of ohms, and is thus at once comparable with any other electrical resistance required.

Electro-motive force, test of battery.

The comparative electro-motive force of a battery may be determined, by means of a differential galvanometer, used as an ordinary horizontal detector, and a set of resistance coils, in a very simple manner. The mode of finding the electro-motive force with this instrument, as recommended by Mr. Latimer Clark, is as follows. This can only be done relatively, in terms of some other standard battery.

Connections for the test.

In order to determine the resistance of the standard and of the other cells to be measured, insert the shunt plugs at A and D, and those at C and B, connecting the plates to the bar under the key, as in the former case, and join up the standard cell in circuit with a set of resistance coils to the terminals A and D, and unplug the resistance coils until a convenient deflection is obtained, say 15°; note the sum of the resistances in circuit, including that of the battery, galvanometer, resistance coil, and connecting wires; now change the cell for another, and by readjusting the resistance coils bring the needle again to the same deflection, 15°; having again found the total resistance in circuit, the relative electro-motive forces of the two cells will be directly proportional to those resistances.

The electro-motive force thus determined is comparative; that is to say, the result given by one battery may be compared with that obtained from another, and assuming any given cell as a standard, the value of each, as compared therewith, is obtainable.

Test of electro-motive force and internal resistance of quantity battery.

The electro-motive force and internal resistance of a battery, which is capable of fusing a fine platinum wire, may be found in the manner described for Grove's battery, in *The Course of Instruction in Military Engineering*, page 140, paragraph 303. A simple arrangement of thermo-galvanometer and resistance coils, suitable for this purpose, has been fitted up on the testing table, proposed for service: this is shewn at I, *Plate* LXXXI.

Tests of system combined as a whole.

Having carefully tested the several parts of the apparatus, both mechanically and electrically, in the manner described, they may be put together, precisely in the combination in which they are to be submerged. When electricity is to be the igniting agent, the system should again be tested electrically, as a whole. The results thus obtained would at once indicate whether the whole was in working order or not, and would be strictly comparable with the information obtained by similar tests, applied at any period after the mines had been submerged. A careful record should be kept of the results of all the electrical tests applied, as by preserving the electrical history, so to speak, of any combination, a defect in its electrical condition may be readily discovered, and the nature, position, and extent of such defect indicated, with a considerable degree of certainty, without the necessity of raising the mine out of the water, or in any way disturbing the arrangements employed.

Tests after submersion.

After a mine has been submerged, with electric cable, &c., complete, it should be immediately tested to ascertain that all is right, and similar tests should be applied at intervals to ascertain that the charge remains dry, and, in consequence, efficient; that the electrical resistance of the fuze is such as to indicate certainty of ignition; and that the insulation and conductivity of the electric cable remains good. The nature of the tests applied to ascertain these points, depends upon the nature of the combination in which the mine is arranged: that is to say, whether it is on a circuit-closing or circuit-breaking system, whether the circuit closer is on a branch, or otherwise connected, and the nature of fuze used. The amount of accuracy with which the information, derived from electric tests, may be obtained, depends entirely on the manner in which the several electrical circuits are connected up, and the nature of the tests to be applied must be determined accordingly.

Though it is probable that a great deal remains to be done in perfecting the electrical tests, to be applied to a system of submarine mines after submersion, a very considerable advance has been made in this most important detail, and several modes have been suggested, by which such an amount of knowledge of the state of a submerged mine may be arrived at, that the fact of its

efficiency or inefficiency is known with almost absolute certainty. Such being the case, it is only necessary to say that, on actual service, the moment a fault is discovered by the tests, which seems to indicate a state of inefficiency, the mine should be examined and put right, unless the presence of the enemy or some imperative reason should intervene to prevent it. Time should not be wasted in endeavouring to find out, with absolute certainty, the precise nature and extent of the injury. It is necessary to bear this in mind, because the tendency is to endeavour to arrive at a very definite conclusion, before moving the mine. In carrying on a series of experiments, the case is different: under such circumstances it is most desirable to try and work out the minutest particulars before touching the mine. On service the question of the efficiency or inefficiency of a mine, due to a defect indicated by the tests, must be left to the discretion of the officer in charge, who should, however, be careful not to disturb a mine without a sufficient reason.

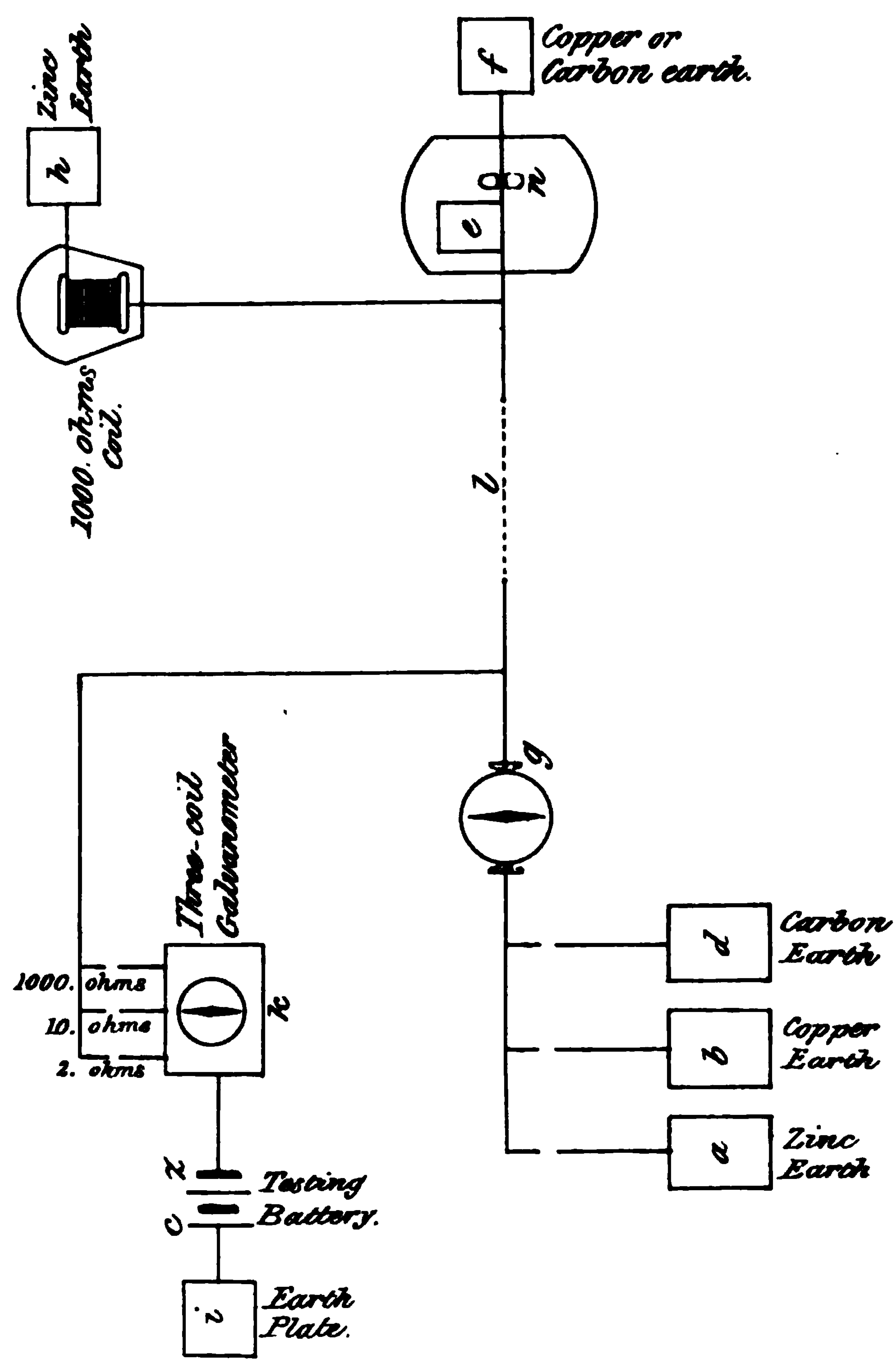
System of electrical tests employed at Sheerness during the years 1871 *and* 1872.

The general idea of the system of testing, applied to the experimental mines at the Nore, during the years 1871 and 1872, is shewn in the diagram, *Plate* LXXXIV. These mines were controlled from an observing station in the vicinity of Garrison Point Fort, Sheerness, and the system employed has, on the whole, given very satisfactory results. The tests applied are of two classes:—1st, that which has been distinguished as the "sea cell test," and, 2nd, that in which battery power, in connection with the three-coil galvanometer M, *Plate* LXXXI., is employed. It is from a comparison of the tests obtained with these two, that the state of the mine is ascertained.

Sea cell test.

The sea cell test is due to the galvanic action set up between any two metals, differing in electrical constitution, when joined by a metallic conductor, so as to form a pair of battery plates, immersed in sea water. Under these circumstances a considerable voltaic current is generated, for example, in the diagram *Plate* LXXXIV., if the copper earth plate *b* be put in metallic connection with the zinc earth plate *h*, through the astatic galvanometer *g*, and with the electric cable *l* and the coil of 1000 ohms, used for testing purposes in connection with the circuit closer, the plates *b* and *h* being immersed in sea water, one near the testing room and the other near the mine, a voltaic current, sufficient to deflect the galvanometer *g* very decidedly, will circulate. The fact that the two earth plates are at a considerable distance apart, varying in the case of submarine mines, as used on service, from one to three miles, does not militate against the conditions as regards the voltaic action. The diagram, shewn in *Plate* LXXXIV., represents the connections and tests employed in the case of a mine, with the high tension fuze and circuit closer on a branch, in one of the systems which has been adopted by the Torpedo Committee for service. In connection with

DIAGRAM OF TESTING CONNECTIONS.



Lithographed at the S. M. E. Chatham.

B. Butler, Corpl. R.E.

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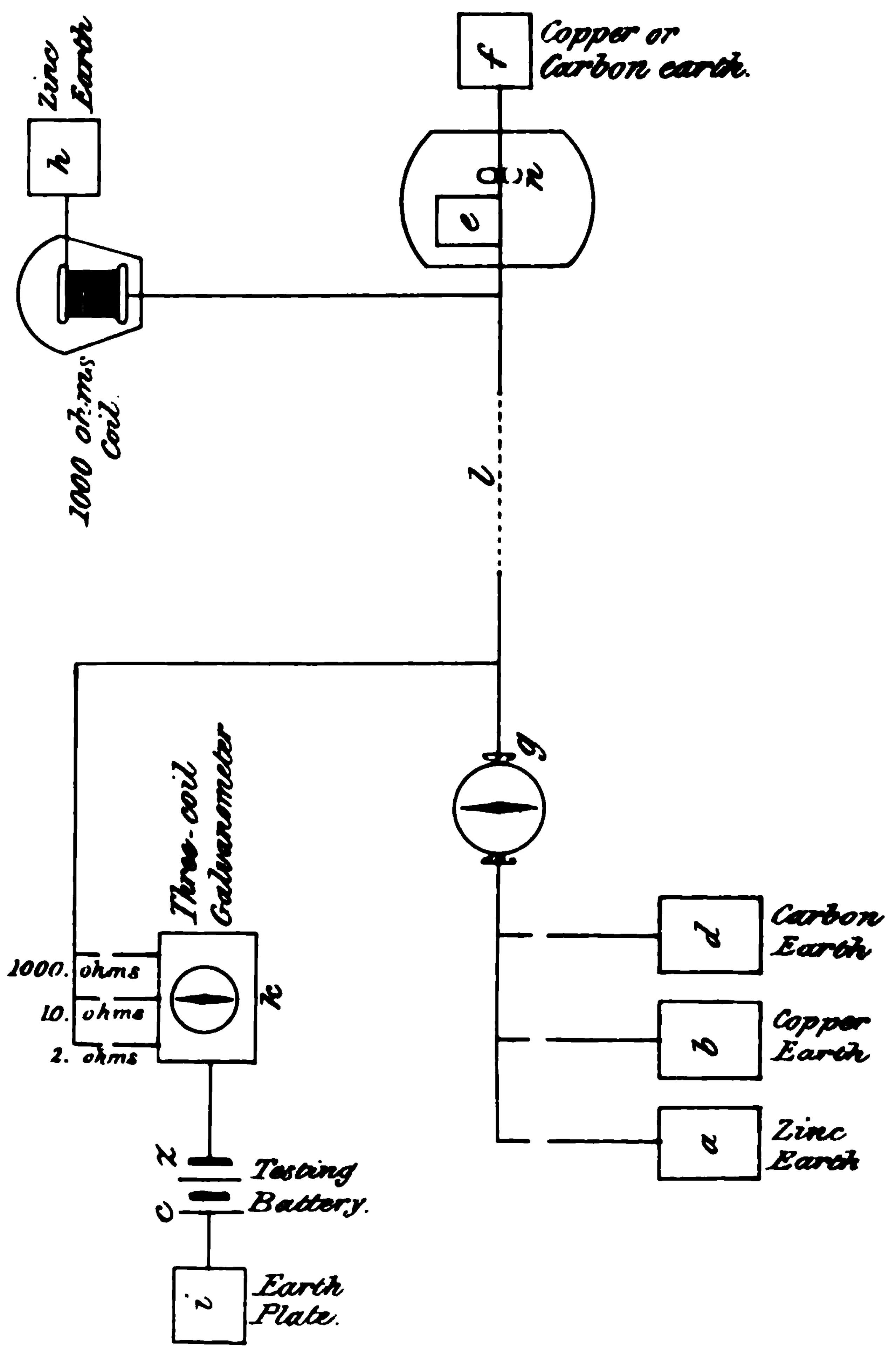
DIAGRAM OF TESTING CONNECTIONS.



Lithographed at the S. M. E. Chatham. B. Butler, Corpl. R.E.

the sea cell test, the three earth plates—*a* of zinc, *b* of copper, and *d* of carbon, are employed in the testing room. These are arranged, so that any one of them may be readily connected with the astatic galvanometer *g*, and, through the electric cable to the mine, with the divided circuit through the fuzes *n* to the carbon, or copper, earth plate *f*, and on the branch, through the resistance coil in the circuit closer, to the zinc earth plate *h*. If the circuits are in good working order, the tests obtained would be somewhat as follows. First suppose the zinc earth plate *a* to be connected to the circuit, we should then have zinc at the home end of the circuit, copper or carbon at the other, on the line through the fuzes, and zinc at the end of the branch connecting the circuit closer: the two plates, *a* and *h* would, (omitting for a moment certain disturbing influences due to the previous circulation of currents, &c.), be neutral to each other, while the earth plate *a*, acting through the high resistance, (about 7,500 ohms), of the fuzes, would be active to the earth plate *f*; this would produce a small deflection of the needle of the galvanometer *g*; we will assume this deflection to be to the left. Again, let us suppose the zinc earth plate *a* disconnected, and the copper earth plate *b* thrown into the circuit, we should then have the copper earth plate *b* active to *h*, through the 1000-ohms resistance, and neutral to *f* through the high resistance, (about 7,500 ohms), of the fuzes: the result would be a very considerable deflection of the galvanometer *g*, and this deflection would be in the opposite direction to that produced when the zinc earth plate *a* was in circuit. Let us now suppose that a defect had arisen in the combination, as for example, that the charge had become wet. To meet this contingency, a zinc earth connection *e*, is arranged within the charge, between the fuzes and the testing room: this earth connection is made by means of the zinc guard of the fuze piece, as described at page 153. Omitting, as before, the effect of the disturbing influences, let us suppose the zinc earth plate *a*, at the home end, switched into the circuit: we should then have zinc at the points *a*, *e*, and *h*, the high resistance of the fuzes eliminating the influence of the copper, or carbon, earth plate *f*. With zinc at both ends of the line, all the immersed plates would be neutral to each other, and there would be no deflection on the astatic galvanometer *g*. Again, if the copper earth plate were switched in at the home end of the line, we should have the zincs at the outer extremities of the branches both active to copper, with the high resistances of the fuzes, which would occur in the perfect circuit, eliminated, and the result would be a very much increased deflection on the galvanometer *g*, such deflection being in the direction due to the influence of the exposed zinc in the wet charge. Again, if the circuit closer were carried away, or if a fault occurred in the insulation of the electric cable, copper would be exposed in the sea water, and the deflections on

Wet charge.

Defects of insulation, &c.

the galvanometer would, by their direction and degree, indicate the fact. The carbon earth plate is used for certain special purposes, such as the depolarization of the earth plates, &c., in a manner which shall be hereafter described.

Tests with 3-coil galvanometer.

In addition to the sea cell test, which gives an indication of the nature of the metal exposed in the sea water, we have the 2nd test applied with 2 Daniell's cells through the 3-coil galvanometer M, *Plate* LXXXI. The object of this test is to ascertain the increase or diminution of the electrical resistance in circuit, and this, in combination with the sea cell test, gives certain specific data by which the nature and extent of the fault may be indicated. The mode of applying this test is simply to pass, first the positive and afterwards the negative current of the two Daniell's cells, through the three coils of the galvanometer, along the line, separately, noting the deflections obtained. When the combination is in working order, a certain, definite series of deflections are given, but should the resistance be increased or diminished, the deflections will at once indicate that increase or diminution. In *Plate* LXXXIV., *c z* shews the testing battery of two Daniell's cells, *i* the earth connection, and *k* the 3-coil galvanometer. In testing any circuit, it is desirable, in order to obtain a maximum of deflection, to employ a galvanometer, having an electrical resistance in its coils nearly equal to that of the circuit to be tested. This circumstance has, in a measure, governed the selection of the resistances in the coils of this particular instrument. The 1000-ohm coil is slightly greater in resistance than the electrical circuits of a mine in working order: the 10-ohm coil approaches in resistance to the electric cable, exclusive of that of the fuzes and circuit closer, and comes into play, when a fault occurs which, more or less, eliminates the charge from the circuit: the 2-ohm coil is intended to give a maximum of deflection with very serious faults, which reduce the resistance of the combination to something approaching that small resistance. It is easily understood that, should anything occur to reduce the resistance of the circuit in connection with the mine materially, such, for example, as a wet charge, or a considerable defect in the insulation of the cable, a much greater increase of deflection, as compared with an efficient working state, would be observed with the 10 or 2-ohm coil in circuit than with the 1000-ohm coil. The object to be attained has been, to construct the coils of smaller resistance in such a manner, that there may be little or no deflection as long as the line remains well insulated, while, at the same time, they may be extremely sensitive to any reduction in the electrical resistance. Practically, the 10-ohms coil is useful in connection with resistances of from 400 to 50 ohms in the system, while the 2-ohm coil comes into play below that point, or from 50 ohms downwards. The object of passing first a positive and afterwards a negative current through the circuit is

to obviate, as far as possible, the disturbing effect of polarization of the earth plates or of the exposed metallic surface of a fault, due to the continuous passage of the current of the shutter signalling battery.

Combined tests with sea cell and 3-coil galvanometer.

The kind of information obtained by the combination of these two tests may best be seen by reference to the following table, which gives the actual tests taken at Sheerness, on two consecutive days, of No. 2 mine of the system, at the Nore. On the 15th of February everything was in excellent working order, and the tests as recorded on that day may be taken as a sample of those which should indicate a mine in good order. On the evening of the 16th of February, a vessel anchored over the electric cable, and, in weighing anchor, early the next morning, fouled the cable with her anchor, and, having been drawn up, it was cut in two with an axe or some sharp instrument, thus producing a small clean exposed surface of copper. In this case, the sea cell test demonstrated the introduction of a fresh metallic surface into the circuit, and gave a decided indication of the absence of zinc at the distant end, while the 3-coil galvanometer indicated a considerable reduction in electrical resistance: this is specially noticeable in the deflections with the 10-ohm and 2-ohm coils in circuit. The deductions to be derived from these tests would be, that the circuit closer was certainly gone, and that a fault, probably due to the rupture of the electric cable, yet still possessing a certain amount of electrical resistance, existed on the circuit. Other indications pointed to the position of the fault as being in the multiple cable, all the mines in the group attached to this cable giving similar tests.

No. of mine and date.	Readings on the astatic galvanometer with sea cell.		Readings on the 3-coil galvanometer with 2 Daniell's cells.						Remarks.
			Negative current.			Positive current.			
No. 2.	Zinc earth at home.	Copper earth at home.	1000 ohm	10 ohm	2 ohm	1000 ohm	10 ohm	2 ohm	Cable severed on night of February 15 to 16, in weighing ship's anchor
Feb. 15th	Nil.	50 Right.	40	2	0	44	2	0	
Feb. 16th	4 Right.*	12 Right.*	55	25	3	57	26	5	

* In consequence of the nature of the injury, which consisted of a clean cut directly across the cable, a very small section of the copper conductor was exposed, which probably accounts, in a measure, for the somewhat exceptional readings obtained with the sea cell test on this occasion.

The deflection to the right in the sea cell tests on the 16th February, may be due to the polarization of the exposed surface of the copper conductor. Disturbing influences of this nature must always be looked for.

Mode of testing adopted by Torpedo Committee.

The mode of testing above described has been adopted by the Torpedo Committee, for the system of mines with high tension fuzes and detached circuit closers, as described in page 152 and those following.

Disturbing influences to sea cell test.

Polarization

In testing in this manner with the sea cell, certain disturbing influences occur, which must be obviated as far as possible. For example, if a carbon earth plate *f*, *Plate* LXXXIV., be employed beyond the charge, the plates become polarized and act in opposition to the current produced by the copper-carbon sea cell; in order to obviate this, it is necessary to depolarize the system, by the application of a short current of opposite sign from a few cells of a voltaic battery, to bring the plates to what may be termed a neutral state, under which circumstances alone they are in a condition to give a correct deflection on the galvanometer. The chief polarization takes place on the zinc plate, which becomes coated with hydrogen, and gives readings in the same direction on the galvanometer when connected to the home zinc, as when connected to the home copper. The exposed metallic conductor of an electric cable becomes similarly polarized, when subjected to the passage of a continuous battery current, and it must be depolarized by similar means. The polarization of the plates of any single-fluid battery, including the Leclanché, is very rapid. The moment the battery circuit is closed, the plates become polarized, and much care and dexterity is required to depolarize them, when making the test for the internal resistance of the battery, as described at page 285. Unless they are carefully depolarized, the internal resistance of the battery, found in this manner, will appear to be very much larger than it really is.

The following demonstration, of the general principles on which the liquid resistance of a battery is calculated by the differential galvanometer, shews that the result found by that method is not correct in the case of single-fluid batteries, in which the electro-negative plate assumes a different degree of polarization, according to the altered resistance in the circuit in each case.

Let g be the resistance of each coil of the galvanometer.

s ,, ,, shunt.

x ,, ,, the battery.

w ,, unplugged.

e be the electro-motive force, when the current passes through one coil.

e_1 be the electro-motive force when the current passes through two coils.

c be the current in the first case.

c_1 ,, second case.

By Ohm's law we have

$$c = \frac{e}{x + \frac{g.s}{g+s}} \quad (1) \quad \text{and}$$

$$c_1 = \frac{e_1}{x + 2.\frac{g.s}{g+s} + w} \quad (2)$$

But c_1 only equals $\frac{c}{2}$, as it passes through twice the resistance in the coils to produce the same deflection.

$$\therefore \frac{e}{x + \frac{g.s}{g+s}} = \frac{2.e_1}{x + 2.\frac{g.s}{g+s} + w} \quad (3)$$

Now if $e = e_1$, as is the case in the Daniell battery, or others in which the electro-negative plate does not polarize rapidly, from equation (3) we get

$$2\,x + 2.\frac{g.s}{g+s} = x + 2.\frac{g.s}{g+s} + w \therefore x = w. \quad (4)$$

But if e were not equal to e_1, as would be the case when the electro-negative plate was carbon, equation (4) would not hold good.

In such cases, the currents would have to be measured by the swing of a needle or the fusion of platinum wire, for the establishment of equations (1) and (2).

Contact of galvanized protecting wires.

The outer protecting covering of the form of electric cable used for submarine mining purposes, being partly formed of galvanized iron wires, any accidental contact of these, introduced into the system, would produce a copper-zinc sea cell, and give a deflection similar in character to that produced by the zinc plate in a wet charge. This must not be lost sight of in reference to the tests; it has been found in practice, however, that a defect of this nature rarely occurs.

Value of electrical tests depends on comparison.

All electrical tests, made at any period after the submersion of a charge, are simply comparisons with the electrical conditions necessary to practical working perfection, which, to ensure success, must have existed when it was first placed in position. Any deviations from these conditions would indicate faults in the system, and would be demonstrated by the difference between the results of the tests obtained, as compared with those which ought to exist in a perfect combination. It is very essential, therefore, that a strict record should be kept of all tests applied to each mine and cable, with the results obtained.

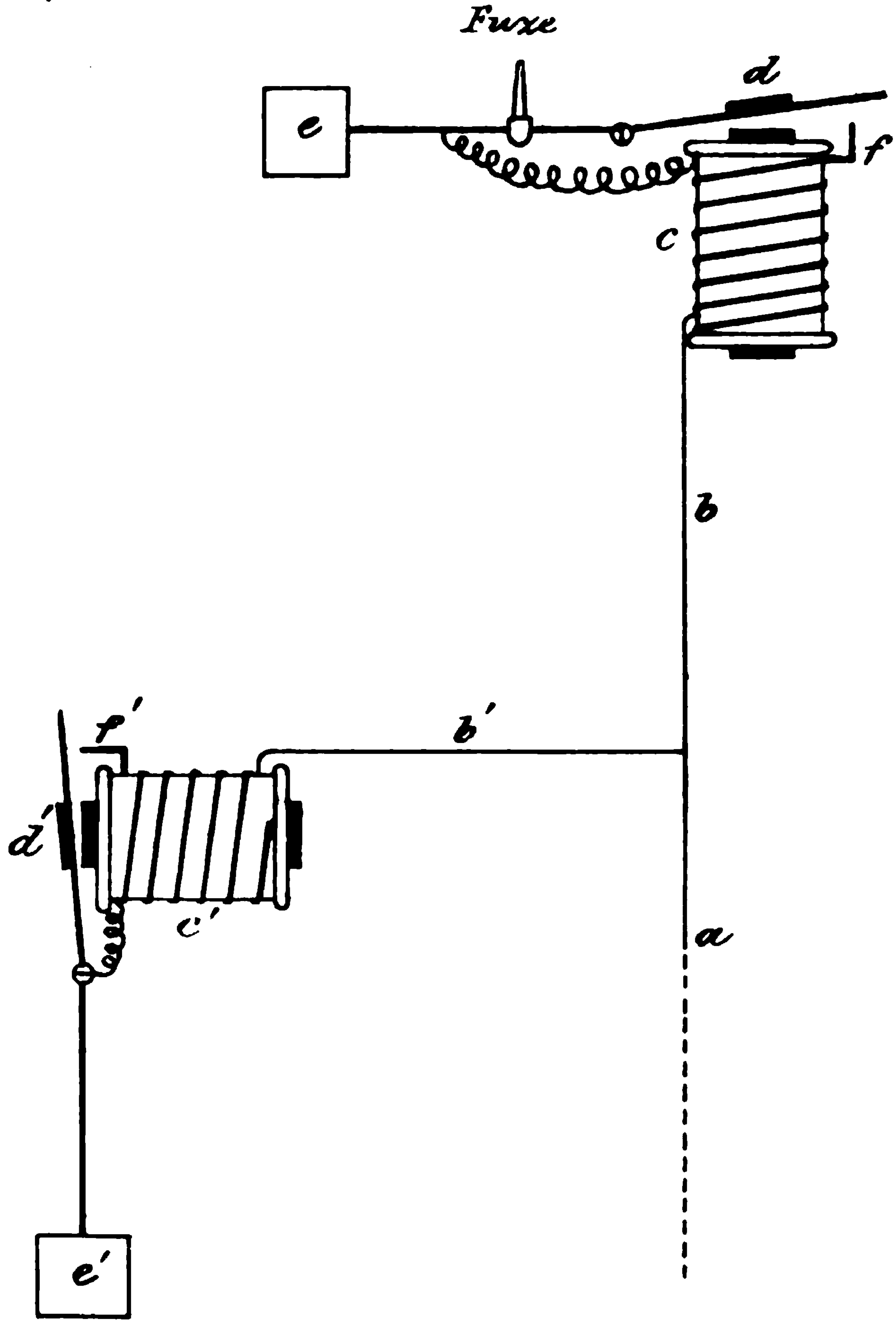
Mode of testing proposed by Captain Armstrong, R.E.

Captain R. Y. Armstrong, R.E., has proposed the following mode of testing, for use with a detached circuit closer and platinum wire fuze:—in this proposed combination the connections are the same as those described at pages 152 and 156, the only difference being that a single platinum wire fuze is employed, instead of two of those adapted for electricity of high tension, connected in divided circuit. *Plate* LXXXV.

shews a diagram of the details of this combination. *a* is the electric cable from the shore, *b* the electric cable connecting the charge through the fuze to earth; *b′* is the electric cable connecting the circuit closer; *c* and *c′* are polarised electro-magnets, one *c*, in the charge, arranged to be formed by a positive current, that is to say, the wire of which it is formed so wound on, as to increase the polarity of the extremity of the electro-magnet nearest the armature when a positive current is passed through it, and to diminish it when a negative current circulates; the other, *c′*, arranged to be worked by a negative current, the coil being so wound on as to produce an influence exactly the reverse of *c*. In this way it is easily understood that, if a positive current is passed along the line, the armature *d* will be attracted, while the armature *d′* will remain unaffected, while, if a negative current is passed, the armature *d′* will be attracted, while *d* remains unmoved. Thick wires, in direct circuit with the branches *b* and *b′*, are coiled round the electro-magnets, in addition to the thin wire coils of the electro-magnets themselves:—these terminate in two contact points *f* and *f′*, which latter are so arranged, that when the armatures are attracted they may come in contact and complete the circuit through them, while in their normal state breaks exist between them and the armatures. The thin wire coils of the electro-magnets proper, have each a resistance of 1000 ohms, and are connected direct to earth, as shewn in the diagram, *Plate* LXXXV., by the earth plates *e* and *e′*:—they are so arranged that 12 cells, or more, of a Daniell's battery will make them act, while with a lesser number the current will pass through the longer coil of the electro-magnet and on direct to earth. As a modification of an idea of Qr.-Master Sergeant J. Mathieson, R.E., it is also proposed to place a second platinum wire fuze, on the branch cable connecting the circuit closer to the charge, as an addition to this system. This fuze would be in direct circuit between the junction of the branch *b′*, *Plate* LXXXV., with the main cable *a* and the circuit closer. It is intended for use in the event of the latter becoming wet, under which circumstances the charge could still be fired: the current of the battery would first pass to earth and fire the fuze on the branch *b,′* thus insulating the latter, after which it would pass through and fire the mine itself.

System of testing. In the system of testing proposed by Captain Armstrong, the following results are obtained:—With the positive current of 2 Daniell's cells, applied through the 2-ohm coil of the 3-coil galvanometer, a slight move only of the needle should occur. With the negative current of 2 Daniell's cells, similarly applied, a slight move of the galvanometer needle should similarly result. With the positive current of 12 Daniell's cells, applied through the same coil, a large deflection should occur, the current in this case would form an electro-magnet *c* in the mine, of sufficient power

CAPTAIN ARMSTRONG'S SYSTEM OF TESTING.



Lithographed at the S. M. E., Chatham. *B. Butler, Corpl. R. E.*

to attract the armature *d*, and, cutting out the long coil *c* of the electro-magnet, pass direct to earth through the contact point *f*, while, on the contrary, it would not affect the electro-magnet *c'*. With the negative current of 12 Daniell's cells through the 2-ohm coil, a large deflection should also occur, due to the attraction of the armature *d'*. In this way both the circuits could be separately tested, and any defect in the system would be indicated, by a deviation from the deflection which should be obtained with the circuits in good working order. The advantage of this arrangement is, that by it a platinum wire fuze can be used on the circuit-closing system, and that testing is simplified.

A mine and circuit closer, arranged on Captain Armstrong's system, have been submerged for trial at the Nore, for nearly 12 months, and subjected to much rough treatment from the effects of weather and passing vessels. When taken up for examination, the electro-magnets were found to be in perfect working order, and that in the circuit closer was unaffected by the condensation produced by two table spoonsful of water, which had got into the apparatus.

Testing arrangements for platinum and tension fuze differ.

Different testing arrangements must be adopted, according to the system on which the mines are to be fired. If a platinum wire fuze and circuit breaker be employed, as in *Plate* LXXIV., *Fig.* 1, page 250, a large number of Daniell's cells may be employed without danger, and every part of the system may be tested directly, including the fuze and circuit breaker beyond it. If a high tension fuze and circuit closer, arranged as in *Plate* LXXIV., *Fig.* 2, page 251, be employed, a small number of Daniell's, or some similar cells, must be used, with a very sensitive galvanometer.

C. F. Varley's loop test for discovery of position of fault.

Should an injury to the insulation of the electric cable, either between the fuze and the shore, or beyond and between it and the circuit closer, be indicated by means of the sea cell test, when the platinum wire fuze and circuit breaker is used, its position might be discovered in the manner shown in *Plate* LXXXVI. *Fig.* 1. The positive pole of the battery *c z* being put to earth at *e*, the negative pole should be attached to a differential galvanometer, or Wheatstone's bridge, one terminal of which should be connected to the defective cable *l*, while the other should be connected with one terminal of a set of resistance coils *r*. A well insulated cable *l'*, of known electrical resistance, should be attached to the other terminal of the resistance coils *r*, and should be paid out to reach the circuit breaker attached to the defective line. The electric cable attached to the circuit breaker should be disconnected therefrom, and attached by a temporary insulated joint, or Mathieson's connector, to the line *l'*. Supposing the defect in the line to exist at the point *f*, it is easily seen, on reference to the diagram, that the current from the battery would divide itself between the two circuits open to it, returning through the leak

at f to the earth plate e: and if the resistance in these two circuits were equal, the needle would stand at zero, and this equality would be established by unplugging the coils r.

Let x = the distance, in terms of electrical resistance, of the fault from the galvanometer g; y = the distance from the fault to the circuit breaker; L = the total resistance of the circuit l, including fuze and electric cable up to and connecting the circuit breaker, (this should be ascertained by previous tests, when the cable and connections were in good working order); L_1 = the resistance of the line l'; and R = the unplugged resistance in the coils when the galvanometer needle stands at zero. In this way we obtain two equations, viz. :—

$$x + y = L$$
$$\text{and } x = R + L_1 + y$$

from which the values of x and y, in terms of electrical resistance, which would be readily convertable into length, could be easily determined. Should the fault exist near the home end of the line, it would be necessary to place the resistance coils in connection with the same coil of the galvanometer as the defective line, in order to make the two circuits balance, the resistance of x being necessarily small under such circumstances. In this combination it will be observed, that the electrical resistance of the defect is equally divided between the two circuits, and its effect does not in any way disturb the conditions necessary to the truth of the equations employed.

A large number of Daniell's cells may be used with platinum fuze.

A large number of Daniell's cells may be used in making this test with the platinum wire fuze, without any chance of an accident. In working a circuit-breaking system in connection with a platinum wire fuze, it would be convenient to keep an electric cable, from the electrical room in the fort, to the vicinity of the mines, permanently in position, for the tests described. This line would also serve for telegraphic communication, which would in all cases be required under any circumstances.

Earth connection in top of circuit breaker for convenience of testing.

In order to render this system for the discovery of the position of a fault effective, some means must be adopted by which a connection with the electric cable in the vicinity of a circuit breaker may be rapidly made. The circuit breakers of a system would generally be very close to the surface at low water, and a little extra length of electric cable, sufficient to enable its extremity to be brought well above the surface, with a joint capable of being readily opened—one of Mathieson's connectors, for example, would answer every purpose. This and other testing arrangements have been much facilitated, by placing the connection with the earth plate, in a chamber in the top of the wooden jacket of the circuit closer or breaker, in the form approved for service by the Torpedo Committee.

Blavier's formula for

When no return wire, as l', *Plate* LXXXVI., *Fig.* 1 is used, the position and extent of a fault on a long line of submerged,

ELECTRICAL TESTING ARRANGEMENTS.

Fig. 1.

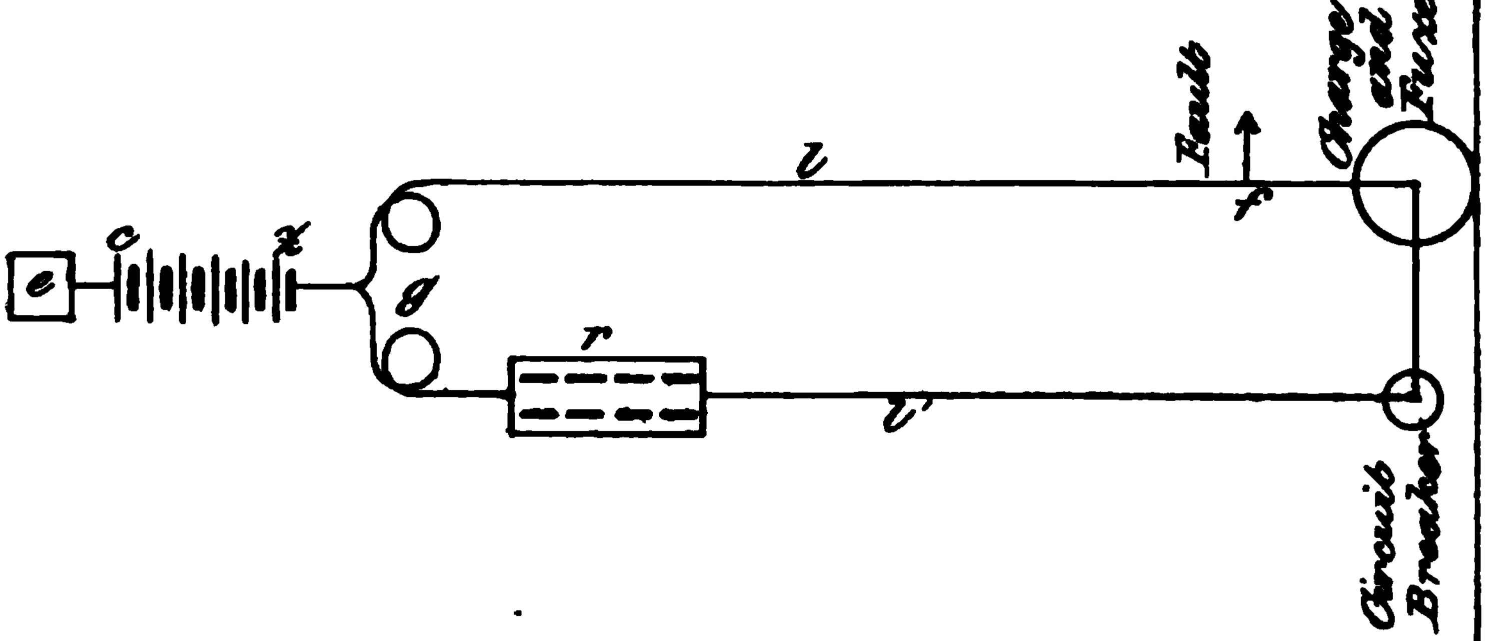
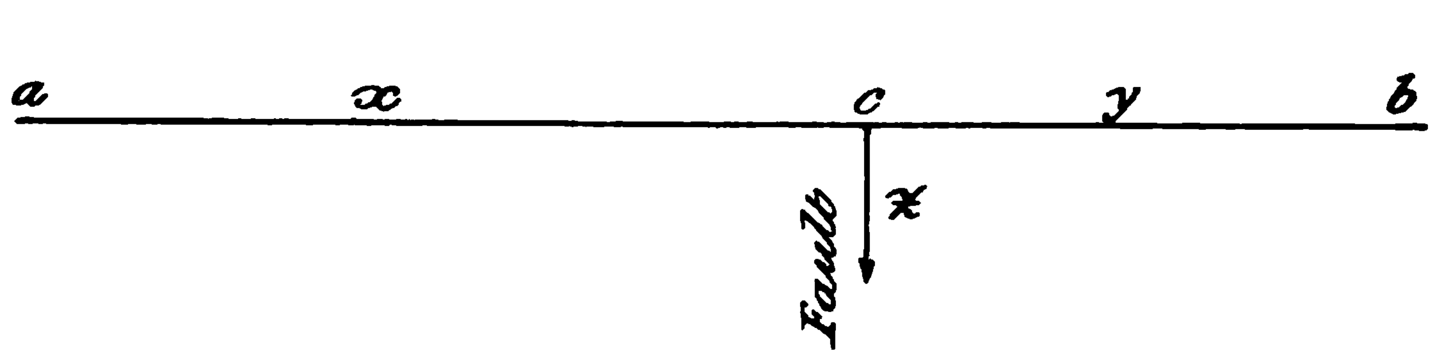


Fig. 2.



Lithographed at the S. M. E. Chatham. *B. Butler, Corpl. R. E.*

electric cable, such a length, for example, as that employed in most of the submarine telegraph lines, may be determined by means of Blavier's formula, as follows:—Let $a\,b$, *Plate* LXXXVI. *Fig.* 2, represent the line, a being the home and b the distant extremity, and suppose a fault of unknown electrical resistance to exist at c. Let x = the resistance of the portion $a\,c$, from the home end to the fault; let y = the resistance of the portion $c\,b$ from the fault to the earth connection at the distant end; and let z = the electrical resistance of the fault itself. Let R = the resistance of the line and connections when in good working order, derived from previous experiment; let S = the resistance of the faulty line when to earth at b; and let T = the resistance of the faulty line when insulated at b. From these we derive the following equations—

discovery of extent and position of a fault.

$$x + y = \mathrm{R} \quad \ldots\ldots \quad (1)$$

$$x + z = \mathrm{T} \quad \ldots\ldots \quad (2)$$

$$x + \frac{y \, . \, z}{y + z} = \mathrm{S} \quad \ldots\ldots \quad (3)$$

$$\text{From (1) } y = \mathrm{R} - x \quad \ldots\ldots \quad (4)$$

$$\text{,, (2) } z = \mathrm{T} - x \quad \ldots\ldots \quad (5)$$

Substituting these values in equation (3) we have

$$x + \frac{(\mathrm{R} - x) \times (\mathrm{T} - x)}{\mathrm{R} - x + \mathrm{T} - x} = \mathrm{S} \quad \ldots\ldots \quad (6)$$

Multiplying both sides by the denominator we get

$$(\mathrm{R} + \mathrm{T})\,x - 2\,x^2 + \mathrm{R}\,.\,\mathrm{T} - (\mathrm{R} + \mathrm{T})\,x + x^2$$
$$= (\mathrm{R} + \mathrm{T})\,\mathrm{S} - 2\,x.\,\mathrm{S} \quad \ldots\ldots \quad (7)$$

From which we obtain

$$\mathrm{R}\,.\,\mathrm{T} - x^2 = (\mathrm{R} + \mathrm{T})\,.\,\mathrm{S} - 2\,x\,.\,\mathrm{S} \quad \ldots\ldots \quad (8)$$

$$\text{and } x^2 - 2\,\mathrm{S}\,.\,x + \mathrm{R}\,.\,\mathrm{S} + \mathrm{T}\,.\,\mathrm{S} - \mathrm{R}\,.\,\mathrm{T} = 0 \quad \ldots\ldots \quad (9)$$

$$\therefore\ x = \mathrm{S} + \sqrt{\mathrm{S}^2 + \mathrm{T}.\mathrm{R} - \mathrm{T}.\mathrm{S} - \mathrm{R}\,.\,\mathrm{S}} \quad \ldots\ldots \quad (10)$$

$$\text{or } x = \mathrm{S} + \sqrt{(\mathrm{R} - \mathrm{S}) \times (\mathrm{T} - \mathrm{S})} \quad \ldots\ldots \quad (11)$$

Substituting this value of x in equation (5) we have

$$z = \mathrm{T} - \mathrm{S} - \sqrt{(\mathrm{R} - \mathrm{S}) \times (\mathrm{T} - \mathrm{S})} \quad \ldots\ldots \quad (12)$$

From these equations the values of x, y and z, in terms of electrical resistance, are readily obtainable, and the position of the fault may be discovered by converting the values of x and y into length.

If the value of x has been previously obtained, by means of Varley's loop test, that of z is readily obtainable from equation (2).

Blavier's method for determining the position and extent of a fault, is chiefly useful for long lengths of electric cable, the limits of accuracy, between which the information is obtained, being somewhat large. It would scarcely be applicable to the short lengths employed for submarine mining purposes, but is given here for general information.

One mode by which the extent of a defect in an electric cable may be roughly determined, is given by Lieutenant (now Com-

Mode of determining

extent of fault, employed by Lieutenant Fisher, R.N.

mander) Fisher, R.N., in his work, entitled *A Short Treatise* . *Electricity*, as follows:—

"Depolarize the main and earth wires by connecting them thus neutralizing the free electricity. After some minutes, test the depolarization by again making contact between earth, galvanometer, and main wire; if no movement of the needle takes place, the neutralization is complete. Attach earth wire to te battery, and with the other pole of test battery make contact wi main wire (counting "one") and then immediately remove it. Now the earth and main wires are slightly polarized, so see if the 'return current' can be obtained by attaching them to the galvanometer. If the needle moves now it indicates a large fault for the wires were not connected with the test battery for mu more than a second. If the needle does not deflect, repeat the operation; leaving the wires this time a little longer in the close circuit, and so on until the return current is obtained.

"It will be obvious, from what has been said, that the longer the test battery is in the circuit before the 'return current' is obtained, the smaller will be the fault."

The current, called the "return current," obtained in this case is due to the polarization of the exposed metallic conductor of the electric cable; and when a minutely small surface of metal is thus exposed, the momentary circulation of the current does not produce sufficient polarity, to establish such a current as would deflect the needle of the galvanometer.

In making tests of this nature much dexterity and previous practice is required, as well as considerable electrical skill.

The difficulty of the problem arises from several causes, described by Mr. Culley, as follows:—

Cable current.

"1.—As the metallic conductor is exposed, it forms galvanic elements or batteries, with the iron sheath and the salt water, so that a positive current flows from the cable, through the testing galvanometer, to earth; this is steady and constant if the cable is not disturbed."

"2.—We have to deal with two unknown resistances; that of the wire itself, and that between the exposed part and the earth: the first is constant, the second very variable, because

"3.—The action of the current alters the resistance at the point at which the metal touches the water, by coating it with substances which differ in conductibility; and at the same time the apparent resistance is still further altered, by the currents of polarization set up by these substances."

"The action which takes place, can be shewn by placing a piece of cable in a glass filled with salt water, and applying a current from 40 or 50 cells, one pole of the battery being connected to the iron sheath, the other to the copper conducting wire. The portion of the cable connected to the zinc, gives off a stream of hydrogen, while the other becomes coated with a chloride of t

metal. Thus, if the negative pole is connected to the conductor, and the positive to the sheath, chloride of iron is formed, and if the connections are reversed, chloride of copper is produced."

"Let us now connect a galvanometer to the cable, in such a manner that the current from the cable battery of copper and iron in salt water, called 'the cable current,' shall deflect the needle to the *right*; the iron element being of course always on the earth."

"If a negative current is now sent into the cable, its direction coincides with that of the cable current, and does not affect the direction of the deflection."

"But the superior force of the testing battery overcomes the cable current, and polarizes its elements. The copper wire becomes coated with hydrogen, the iron sheath with chloride of iron, so that when the testing battery current is cut off, and the cable battery is again free to act, its action is reversed, and the needle moves to the *left*, under the influence of the current of polarization."

"But the hydrogen gradually enters into combination and disappears from the wire, the polarization ceases, the needle returns towards zero, passes it, and finally takes up its former position to the right, under the influence of the cable battery in its normal state."

"On the other hand, if we test with copper, instead of zinc, the needle is deflected to the left, the cable battery again acts as a decomposition cell, but the polarization is now in an opposite direction, the copper being coated with its chloride, and the iron with hydrogen. When the testing current ceases, the needle therefore moves to the right, and continues permanently deflected in that direction, because the normal current from the cable battery is now in the same direction as the current of polarization."

Condition of cable best suited for resistance test.

"If we apply a succession of short zinc currents, after the wire has been coated with the chloride, the needle will still take up a right hand deflection after the battery contact has been broken; but the deflection will decrease after each test, and will finally be reversed. The deflection to the right is due to the polarization set up by the chloride of copper, each application of the zinc current reduces a portion of this chloride, and assists also in removing it mechanically by the action of the hydrogen; until after a time the chloride disappears, and is replaced by hydrogen. The sign of the polarization is then changed, and the direction of the needle is changed also. But there is a moment when the opposite actions of the hydrogen and chloride are apparently balanced, so that the cable battery is inert, and the end of the wire unpolarized and probably uncoated. Then, and then only, can its correct resistance be determined. The object of the special method of test, is to produce this condition."

Mode of

"The test for distance is best made with a differential gal-

applying resistance test.

vanometer. First ascertain the approximate resistance in the ordinary way, and clean the exposed wire from the dirt and the salts with which it would be coated, by applying a zinc current for several hours, occasionally reversing it to get rid of any deposit of soda which may occur. The surface will be roughened by the re-deposit of the copper, which has been dissolved, and will therefore more readily throw off the hydrogen evolved by the zinc current. Next, apply a positive current for the purpose of coating the wire with chloride of copper, and finally test with the negative current. The action of the current set up by the chloride of copper, will make the resistance appear less than it really is; but as the chloride is gradually reduced by the testing current, in the manner which has just been explained, the resistance will appear to increase, moment by moment, and the resistance coils must be lengthened, unit by unit, to balance the resistance of the cable, so as to keep the needle at zero, until it passes over to the opposite side suddenly, under the influence of the change of polarization, caused by the copious evolution of hydrogen, which will follow. The increase of apparent resistance and the consequent movement of the needle, is slow and gradual, so long as the hydrogen is employed in reducing the chloride, but after the reduction is complete, and the chloride has disappeared, the increase in resistance is enormous and almost instantaneous. Unless, therefore, the resistance of the cable has been carefully balanced, so as to follow the variation of the current throughout, the test will not succeed, because the neutral condition lasts too short a time to permit the adjustment of the resistance coils."

Much dexterity required in making resistance test.

"In any case a certain dexterity is required, which can only be obtained by practice; but, fortunately, the practice may be had conveniently upon an artificial fault, or a piece of insulated wire in a tin can, filled with salt water, and connected to a set of resistance coils. Induction does not affect the test, and as in any ordinary cable the insulation is practically perfect, its resistance can be represented as accurately by a rheostat, as by an actual cable. The higher the tension of the battery, the less does the opposing current of polarization affect the result, for its force seldom exceeds two or three cells. The measurement is therefore made with a battery of as high a tension as can be conveniently procured, 60 cells or more."

Behaviour of a fault depends on length of wire exposed.

"The behaviour of a fault varies with the length of wire exposed; a short fault polarizes and depolarizes very rapidly; its changes in resistance are correspondingly rapid and its resistance great. If the exposed wire is long, the changes are slower and more readily observed; the resistance of the fault is also less."

"After having well studied the changes of the fault itself, make an artificial fault by placing a piece of the cable core in a tin can, filled with salt water, and alter the length of the exposed

wire until it behaves in the same manner as the cable, and then find its resistance, which will be very nearly the same as that of the real fault; so that the distance of the break will be the tested resistance of the cable less that of the artificial fault."

"It is a convenient plan to form a table of the resistance of exposed wire of various lengths with 6 and 60 cells, adding resistances by a rheostat, using the negative current and allowing the exposed wire to take up its maximum resistance. The tests with the 6 cells will be always higher than those with 60, that is to say, the resistance of the fault will always appear higher when tested with the lower power, and the difference between the apparent and real resistance will also increase gradually, as the length of the cable itself or the resistance added by a rheostat increases; the length of exposed wire being constant."

"If a cable is found to give, with 6 and 60 cells, two results corresponding to some two in the table, it is probable that the length and resistance of the exposed wire is the same as that of the artificial fault used in the formation of the table, and, therefore, that the resistance between the testing station and the fault is equal to the resistance added to the artificial fault."

Personal equation of observer.

"So much, however, depends upon the manner in which the tests for the table were taken, or upon what we may call the 'personal equation' of the observer, that every one should form a table for himself. The cable must be treated in precisely the same manner as the artificial fault, and therefore no table will be perfectly correct unless it is made just before the cable is tested, in order that the precise manipulation may not be forgotten."

The above remarks are made with reference to the test of submarine cables of considerable length, and though there is not so much difficulty in testing the short lines used for submarine mines, still the same conditions exist and must be guarded against and taken into consideration on all occasions. Unless this is done anomalous results, caused by the disturbing influences above mentioned, will be obtained and it is necessary to guard against their acceptance as due to defects of insulation alone.

Insulation injured at points where motion occurs.

Injury to the insulation of the electric cable necessarily occurs at those points where it is subjected to friction, and in practice, the points where it is attached to the sinker or mooring apparatus, where it enters the case and where it joins the circuit closer, are those where injury has been most frequently found. This is due to the slight motion produced by the action of the water, and special precautions must be adopted to protect the cable at such points.

System of electrical testing for tension fuze approved by

The following system of testing, as applied to mines supplied with the tension fuze, (No. 6, Detonator, Electric, Abel, Submarine), has been approved by the Torpedo Committee.

When a system of submarine mines has been placed in position, daily electrical tests should be taken of each mine to ascertain

the Torpedo Committee.

its condition. Each mine, at the observing station, should be in circuit with its shutter and corresponding terminal at the observing arc. The tests will then be made as follows :—

1st. The connections on shore, to ascertain,

A. Whether the earth plates at the station are in working order.

B. Whether the signalling batteries are in proper order.

C. Whether the adjustments of the shutter springs are correct.

D. Whether the connections inside the shutter boxes are good.

E. Whether the test battery is in proper order.

2nd. The submerged mine to ascertain,

F. Whether the circuit closer, with its earth plate is on.

G. Whether the continuity or insulation of the electric cables, and the insulation of the joints, are good.

H. Whether the charge is dry.

Tests of earth plates.

Great care must be taken in making the first series of tests, and the following points must be attended to. To ascertain that the circuit of the earth plates at home is correct. This necessitates an examination of the plates themselves, to see that they are not coated with any foreign substance, that the connection of the plate with the conducting wire is good, and that the point of junction is well insulated with a sound coating of pitch. The pitch is liable to crack after a time, and should then be made sound again by the application of a heated wire. Should the method of keeping the earth plates in a bucket in the testing room, proposed by Mr. Brown, and described at page 188, be adopted, the sea water in the bucket should be changed as soon as any cloudiness appears. The plates can be kept out of the bucket except at the time of testing. This will ensure their being examined when they are put in again. Each plate should be tested separately, by taking a reading on the astatic galvanometer, attaching the leading wires from H_1, H_2, H_3, &c. in succession to A, *Plate* LXXXI., and from H_8 to B on the test table, and noting the deflection. It should also be noted whether the needle throws towards the active metal, (zinc), or the passive metal, (copper). This will depend on the way the coils of the galvanometer are wound, but will be the same for all subsequent observations if the connections on the test table be made in the same order, that is to say, whatever arrangement is in circuit, the position of the active or passive element should at once be indicated by the direction of the throw of the needle. It is convenient so to arrange the connections, that the throw of the needle shall always be in the direction of the electric current, for example towards the zinc when copper and zinc elements are in circuit. The deflections observed on the astatic galvanometer, show whether the electro-motive force of each of the earth plates employed as a sea cell is unaltered. The activity of the earth

plates may also be examined on the three-coil galvanometer, when, if everything is correct, no great difference would be observed in the readings on the 1000-coil and 10-coil, the resistance of the sea connection, between the two plates, being practically nil. The following readings, or something approaching to them, should be observed on the three-coil galvanometer, under the several conditions specified.

	1000 coil.	10 coil.	2 coil.
With zinc and copper in the sea	28	27	10
With one Daniell's cell on short circuit ...	40	42	17
With zinc and copper in the bucket ...	32	23	6

If, however, any great resistance exists in the circuit, a reading on the 1000-coil only will be observed. For working purposes, that coil of this latter galvanometer is most sensitive, the resistance of which approximates most nearly to the resistance of the circuit under examination.

Casualties likely to happen to earth plates.

The casualties that are likely to happen to the earth plates are:—

(*a*). Deposit on their surface of an oxide, chloride, or some foreign substance.

(*b*). Disconnection from their connecting wire.

(*c*). The insulation of the connecting wire may be defective.

(*d*). The soldered joint may be defective.

In case (*a*), the electro-motive force would be reduced, and small readings would be observed on both kinds of galvanometer. In the case (*b*), with a bare copper wire showing, we might still get the full electro-motive force, but great resistance in the circuit would be indicated, by the reduced readings on the smaller coils of the 3-coil galvanometer. In the case (*c*), the readings on all three coils would be reduced. In the last case (*d*), increased resistance would be observed.

In connection with the testing room, the following earth plates, as already explained, are employed:—

1. Test, copper,
2. ,, zinc,
3. Signalling earth, zinc,
4. Common earth, zinc,
5. Firing earth, zinc,

} In the sea..

The earths should be tested in the following order. 1st. The test zinc and test copper, in the sea; these plates are used for no other purpose but testing, so that they may not be subjected to any polarizing influence from batteries or other sources. Then the zinc earths in the sea connected to the positive poles of the batteries. The zinc, tin, copper, and carbon earths in the bucket are afterwards tried; and lastly, the earth connected to the negative pole of the firing battery.

Tests of signalling batteries. The condition of the signalling batteries is next tested by means of the 3-coil galvanometer, the other terminal of the galvanometer being connected to the common earth, H_8. In this way the battery and the earth are tested simultaneously, by means of the deflections obtained.

Test of adjustment of shutters. The adjustment of the shutters is next examined. For this purpose, two Leclanché cells are connected, on short circuit, with the box of firing resistance coils and the coils of each shutter. the spring of each shutter being so regulated, as to allow the armature to be attracted over, when the two cells and 60 ohms of resistance are in circuit. A key of the form shewn in *Plate* LXVII., *Fig.* 4, should be introduced into the circuit for the sake of convenience, and beginning with 100 ohms unplugged, the spring should be adjusted so that the battery current, when saturating the coils, shall work the armature, when the resistance is reduced from 100 to 60 ohms. This adjustment need not require alteration daily, but should be watched to ensure that the contacts in the apparatus are clean. The distances of the armatures, from the poles of the electro-magnets are regulated once and for all, by the shifting stud marked *c*, *Plate* LXXIX., in the shutter apparatus, and need not be altered. After this adjustment has been completed, a wire from the common earth should be made to touch, in succession, each terminal on the top of the shutter boxes, (always taking care that the firing battery is out of circuit for the time being), and if each shutter drops all the connections are correct.

Tests of the condition of the mine and fuzes. The testing of each individual mine may now be proceeded with. For this purpose, a permanent connection is brought to the test table, from all the test terminals in front of the shutter apparatus, and any given mine may be put in circuit with the test table at pleasure, by shifting its connecting pin from the rear to the front hole. This, at the same time, puts out of circuit the signalling battery, or signalling branch, of that particular mine, but the other mines are not interfered with, and remain in a position to work, if a vessel should come in contact with any of the circuit closers in connection with them.

Sea cell test. The sea cell readings of each mine are taken, first with zinc at home, and secondly with copper at home. To ascertain the nature of the earth circuits abroad; when everything is correct, we have a zinc earth in the circuit closer, working through a resistance of 1000 ohms, and a copper or a graphite plate at the charge, working through 7500 ohms, the combined resistance of a pair of fuzes in divided circuit. The effect of the latter may be disregarded and the action of the first, or zinc plate, only considered. A small reading should be observed in the first case, due to the slight polarization of the zinc earth in the circuit closer, supposing the rest of the circuit is good, being opposed to zinc at home, causing little or no sea cell action, while a large deflection should be observed in the second case, with the copper at home. If now

the lines are depolarized, by reversing the shutter battery for 15 minutes, and the readings are not sensibly changed, it may be concluded that the circuit closer is in connection with the cable under test and consequently with the mine.

Battery tests for mine and fuzes.

The sea cell tests of the several mines having been taken, the battery tests are applied. For this purpose two cells of a Daniell battery are used, that being the maximum number of cells approved for testing. The readings of the two cells should first be taken on the 3-coil galvanometer, on short circuit, to ascertain their condition. Any diminution that may have occurred in their electro-motive force will be at once observed, by reduced readings on the 1000-ohm coil of the galvanometer, while any change in the internal resistance of the cells themselves, will be noted on the 10-ohm coil. A loss of electro-motive force may be caused by the want of sulphate of copper in the copper compartment of the cells, or by particles of copper having been deposited on the zinc. These defects can be easily remedied, by changing the liquid or dropping in a few crystals of sulphate of copper, or by scraping the surface of the zinc plate. An increase of internal resistance is frequently caused, by the liquid in the cells becoming low and requiring replenishment. As the cells used for testing are not employed for any other purpose, they require very little attention and will remain constant for weeks. The test cells having been examined and found correct, their positive and negative poles are respectively connected to the upper and lower bridges of the reversing key L, *Plate* LXXXI., just as a battery is connected with a single-needle instrument. The common zinc earth is then connected to the right hand terminal at the back of the reversing key, and the three-coil galvanometer with the left hand terminal the other binding screw of the galvanometer being connected to the line. By depressing the left hand key the negative current is passed into the line, and the readings are then taken in succession on the 1000, 10, and 2 coils.

It will be observed, that the current will circulate, partly through the resistance bobbin of 1000 ohms in the circuit closer, and partly through the fuzes in the mine. Supposing the resistance of the fuzes to be 15000 ohms each, the resistance of the pair in divided circuit will be 7500 ohms, and the joint resistance of the 1000 ohms in the circuit closer and the fuzes will be $\frac{7500 \times 1000}{7500 + 1000} = 882$ ohms, and supposing $1\frac{1}{2}$ knots of cable to be in circuit, the resistance of this will be 22 ohms, the resistance of the shutter coils 18, and the total resistance of the circuit will be 922 ohms. Some slight loss of resistance may be expected, however, at some one or all of the tubing joints. The current of the two cells, circulating through this resistance, will give a decided reading on the 1000-ohm coil, varying from 30° to 50°, but no reading on the 10 or the 2-ohm coils. Supposing the insulation of the line to be good,

a similar, or slightly greater reading, owing to the polarization of the earth plates by the negative current, will be noted when the positive current is passed into the line. If the insulation is defective, in consequence of a defect of insulation on the line, the resistance of the whole circuit will be reduced and the readings will be increased.

It will be recollected, that the negative current on the line developes hydrogen at the fault, thereby cleansing it and exposing pure metal to the action of the sea. The positive current, on the other hand, forms a chloride of the metal at the fault, and partially insulates it; this latter causes a reduced reading. The amount and the difference of the two sets of readings, thus gives an indication of the character and extent of the leak. For testing purposes, a table should be prepared of the readings on the three coils, with the 2-test cells and resistances varying from 1000 to These readings should be taken, using similar earths in the sea for the return circuit. A comparison of the readings in the table with those registered on the mine and its connections, will give approximate value of the resistance in circuit, which indicates with a certain amount of accuracy, the state of efficiency of the system. It must be remembered, that even large faults in a cable offer very considerable electrical resistance. It has been found that the continuous passage of a positive current, even from the small number of cells composing the signalling battery, through a defect of insulation, will gradually eat away the conductor by forming a chloride of the metal at the fault, which chloride is then dissolved by the sea water and a fresh metallic surface exposed and acted upon in a similar manner, the process being continued till the whole of the exposed metal is destroyed. Bearing this in mind, the signalling battery should always be connected with its *negative pole to the line.*

Casualties which may occur to a mine.

The casualties that may happen to a submerged mine, in the order in which they are likely to occur, are—

1.—Circuit closer carried away.
2.—Defect of insulation on the line.
3.—The cable parted.
4.—Wet circuit closer.
5.—Wet charge.
6.—Loss of continuity.

Tests with a circuit closer carried away.

Although the attachments of the circuit closer are sufficiently strong and durable, to stand any ordinary wear and tear, it is possible that the circuit closer may be occasionally pulled off by the paddles or screw of a passing steamer. In this case the cable would be parted, and a portion of the conducting wire might be exposed, forming an earth connection, or the insulation might be closed over the conducting wire, and the end nearly, if not quite, sealed, and thus insulated. Supposing the conductor to be exposed, the resistance of the whole circuit will be reduced

so as to indicate nearly dead earth. The resistance of ½ an inch of 4 No. 20 wires is about 8 ohms; consequently this amount of wire exposed would reduce the resistance of the whole circuit from 922 to 48 ohms, and the shutter, which is set to a resistance of 60,* must fall. A great change would also be observed in the sea cell readings. With zinc at home, the reading would now be increased from nil to 40 or 50, and with copper at home the reading would be small, shewing that the zinc plate at the circuit closer is gone. As the conducting copper wires are tinned, it is probable that with a tin earth plate at home, the reading would be almost nil, and half-way between copper and zinc, the deflection being at times very unsteady. In the event of the conductor touching the galvanized iron armouring, there might possibly be such a reading as the original zinc plate would give, and the tests, by means of the battery and 3-coil galvanometer, must then be examined. Large readings would also be observed on the 10 and 2-ohm coils, and if a small portion of the conductor only is exposed, the fault could be closed and opened by the alternate passage of the positive and negative currents. If the conducting wire has shrunk into the di-electric, and has thus become partially insulated, which is the general result of a fractured cable, there will be little or no alteration in the battery tests, in consequence of the non-existence of any serious defect of insulation, but the sea cell tests will clearly indicate, that the zinc earth in the circuit closer is disconnected.

Tests with a defect of insulation on line.

The 2nd casualty likely to occur, viz., a defect of insulation on the line, may be caused suddenly by a vessel's anchor fouling the cable, or by continued wear and tear. A sudden loss of insulation would be detected at once, by an increased reading, with zinc at home, in the sea cell tests, and a slightly reduced reading with copper at home. The battery tests would indicate the extent of the fault, by the difference of the readings on the 3-coil galvanometer, with the positive and negative currents. The fault should be closed as much as possible, by the continuous passage of the positive current for a few minutes, and the sea cell readings taken again, in order to ascertain that the circuit closer is not carried away as well. A simple inspection of our table of resistances, would give an approximate value of the resistance of the fault; if it is not sufficiently large to interfere with the signalling, it would not prevent the firing of the mine. As soon, however, as the fault is sufficiently large to drop the shutter, the cable must be under-run, examined, and repaired.

Tests with cable parted.

3rd.—If the cable is parted, the conductor may either be exposed or insulated. If it is exposed, there would be the same indication as when the circuit closer is carried away. The

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* This resistance of 60 is in addition to 18 ohms, in the coils of the electro-magnet of the shutter itself, or 78 ohms in all.

readings would be unsteady, and the resistance would be reduced so low, as to drop the shutter. If the end were sealed, there would be an absence of all indication, under which circumstances the junction box should be raised and the tests repeated from thence, to ascertain whether the fault is in shore or beyond it. It would be a very rare occurrence for the fault to be in shore from the junction box, as the multiple cable could not be injured by any ordinary casualty. Any accident to it would generally reach the seven mines connected to it, for example, if it were deliberately cut, an indication of its severance would be given by the tests on each of the seven conductors, and the fact that the multiple cable had parted, would thus be at once made known.

Indications of wet circuit closer.

4th. A wet circuit closer would generally be due to careless connecting up, as any flaw in the casting ought to be detected in the preliminary tests to which the circuit closers are subjected. Water in the circuit closer would cut the 1000 ohms coil out of circuit, giving a dead earth reading; a strong sea cell reading, due to gun metal action, would also be observed. This casualty would come on gradually and would give intermittent indications, in consequence of the motion of the circuit closer, when acted upon by the tide or waves.

Indications of wet charge.

The 5th casualty, namely a wet charge, might occur suddenly if the case were ruptured by rough usage, for example, by the enemy's countermines, if he adopted such a system of clearing a channel, or it might come on gradually by leakage. If the fuzes are carefully protected by a waterproof composition, there will be no danger of their becoming damp from condensation of moisture in the case, but if any portion is imperfectly protected the fuzes will in course of time become damp, though no serious change might, however, be observed for five or six months. If water leaks into the case, the zinc guard surrounding the fuzes will be moistened, and an electrical connection will be established between it and the water of the sea. The line wire, which is connected with one pole of the fuzes, has also a branch to the zinc guard for the purposes of this test. When the interior of the case is dry, the zinc guard would be perfectly insulated, but should moisture be introduced, the line wire would be put in circuit, through the zinc guard, with the sea water, a defect gradually increasing to dead earth, would be observed on the line, and the fuzes would finally be altogether cut out of circuit. The zinc guard would now operate as a zinc earth plate, and the submerged mine would, in the sea cell tests, give little or no reading on the astatic galvanometer when zinc is used as the earth at home, but there would be a large reading when using a copper earth. These readings would be of the same character as the normal sea cell readings, obtained when the insulation of the submerged mine is good; for example, the reading with copper at home would be increased, owing to the zinc abroad working through

a resistance of the line only, instead of through the 1000-ohms coil, as in the case of the zinc plate in the circuit closer; the battery test would, however, now shew the existence of an earth connection on the line, by increased readings on the 10 and 2 coils of the three-coil galvanometer. The only apppreciable difference when using the positive and negative currents of the test battery, would be due to the polarization of the zinc guard, caused by the continuous passage of the current of the signalling battery; the positive testing current would be assisted, while the negative would be opposed, by the elements introduced. It would not be possible rapidly to close and open such a fault as would occur through a wet charge. The daily readings would shew the gradual change in the tests, the insulation of the circuit would become more and more faulty, the electrical resistance of the circuit would at length approach to that of dead earth and the shutter would fall.

Indications of loss of continuity.

6th. Loss of continuity. When abnormal readings are observed, and before commencing to investigate the nature of the casualty that has occurred, it would be necessary to get rid of the polarized readings in the earth connections or exposed metals in the circuit outside, in contact with sea water. As the signalling battery is always in circuit with the submerged mine, hydrogen would be thrown off at the outside earth plate. This has a tendency to make it active to the zinc plate at home. This action can be dispelled by connecting the line wire to a carbon earth at home for a few minutes, which sets up a galvanic action, reducing the zinc plate in the circuit closer, or other earth outside, to its natural condition; the same effect would be more rapidly obtained, by connecting two cells of a Leclanché battery with the submerged mine, in the opposite direction to that originally taken by the signalling battery, namely, zinc to earth and carbon to line. The application of two cells of a Leclanché battery for a few minutes would generally be sufficient. The fact of the metals outside assuming a natural condition, is indicated by the needle on the astatic galvanometer receding towards the zinc plate at home when that plate is used, and the needle then remaining steady. The exposed end of a conductor invariably gives unsteady readings, in consequence of the motion of the loose extremity in the water: if, however, intermittent dead earth readings occur at intervals, they would indicate a probability of water in the circuit closer.

Readings illustrative of system of testing, and general observations.

The system of testing here described may be further illustrated, by examples of the readings observable when the condition of the submerged mine is satisfactory, and the changes which may be expected, due to the various casualties that are likely to occur. These comparisons must not be taken as affording an invariable rule, but they may help towards forming a definite conclusion as to the nature of the casualty. When it is remembered how

powerfully the water of the sea promotes galvanic action, and the different degrees of accident to which any one portion of the electrical circuit, in connection with a submerged mine, may be exposed, it cannot be expected that two test readings, of even what would appear similar casualties, should exactly agree.

A fractured cable may or may not expose the conductor; loss of insulation, with its consequent loss of current or leakage, may occur in a cable in many forms and degrees; sea water may enter the circuit closer or the case in almost inappreciable quantities. The boisterous action of the sea may, in the former case, cause the water that has entered the circuit closer, to be scattered over the whole of the interior of the apparatus, causing great alteration in the test readings. After which, the water may settle down at the base, and give no further indications for a time. The exposed conductor may be forced into contact with the metal of its own armouring, or with the wire rope to which it is seized, and may subsequently be disengaged and tossed about by the tide and waves. An imperfect joint may gradually yield to the pressure of water at the greatest height of the tides, and its insulation may improve as the pressure of the water decreases. These, and many other circumstances of an analogous nature, may be the cause of the changes observable, when taking the daily tests of a system of submerged mines.

It must be borne in mind, that the test currents circulate principally through the main cable and circuit closer, for the resistance of the fuzes being generally seven and a half times as great as the resistance bobbin in the circuit closer, fifteen parts of the current will go through the latter and only two through the fuzes. An objection may be raised, that no system of testing can be satisfactory, which does not principally and primarily include the fuzes and consequently the mine itself, but inasmuch as the branch wire to the circuit closer is connected to the line wire of the fuze plug itself, inside the cast iron dome of the case, it is evident that any casualty that may happen to the charge, such as its disconnection from the main cable, must of necessity involve the disconnection of the circuit closer, which fact is immediately discovered by the tests. If, however, the circuit closer be gone, the mine and fuzes cannot be tested any longer. If the tests indicate, therefore, that the circuit closer is in connection with the shore, the chance of the charge being disconnected is extremely improbable. In the case of a defect of insulation occurring in the circuit, as the whole length of the cable, from the charge to the testing room, rarely exceeds $1\frac{1}{2}$ miles, of which $1\frac{1}{4}$ miles is along the multiple cable, where an injury is most unlikely to occur, no practicable and simple mode of testing has yet been devised, by which the exact position of the fault could be identified

Whether the defect is actually at the joint connecting the multiple cable within the junction box, at the joint at the mouth of the charge, or at the joint near the base of the circuit closer, the tests would be the same, and if the fault is sufficiently serious to interfere with the signalling and to prevent the mine being fired, the junction box must be raised and the cable under-run till the defect is found. This is an operation which has been found in practice to be easily and quickly performed, and the fault can be repaired as soon as discovered. The tests may be expected to give reliable information as to the nature of the casualty, but when that has been determined, no time should be lost in under-running the cable from the junction box, carefully examining and noting what was wrong, and specially providing against the occurrence of a similar casualty, if brought about by causes that can be anticipated and prevented.

Normal readings of submerged mine in good working order.

The normal readings of a submerged mine, when everything is correct, are as follows.

Astatic galvanometer. Sea cell test.		Battery test. 2-cell Daniell, 3-coil detector.	
Zinc earth at home.	Copper earth at home.	Negative current to line. 1000 10 2	Positive current to line. 1000 10 2
10 left.	52 right.	38 1 0	35 1 0

It may here be observed, that there is a slight reading with the zinc at home, which is due to the graphite or copper earth plate, at the mouth of the charge, producing a slight galvanic action through the fuzes with the zinc earth at home.

Polarizing effect of current of signalling battery.

When the signalling battery has been in circuit for some hours, charging the line, the earth plates at the circuit closer and at the charge become polarized and are rendered more active. A slight change is observed in consequence in all the tests, as follows.

Sea cell test.		Battery test.	
Zinc.	Copper.	Negative.	Positive.
Nil.	56 R	37 1 0	39 1 0

If the current of the two cells of the signalling battery is reversed, that is to say the positive pole connected to the line for 15 minutes, no material change should be observed in the tests, and this is an evidence that all is correct.

Readings with circuit closer carried away, and

If the circuit closer is carried away or disconnected, and the fractured end of the conductor of the electric cable partly or nearly sealed, we may expect to obtain readings somewhat similar to the last, the resistance of the circuit not being materially reduced, and the partially sealed end of the tinned copper con-

end of conductor partially sealed.

ductor being susceptible of the polarizing influence of the signalling battery, and behaving, for a time, like a zinc earth plate. A great change is, however, observable when the line is depolarized for 15 minutes, by the reversal of the signalling battery. The polarization current is completely got rid of, and the readings become of the following character.

Sea cell test.		Battery test.	
Zinc.	Copper.	Negative.	Positive.
50 L	30 R	40 1 0	35 1 0

Readings with circuit closer carried away, and end of conductor exposed.

If the circuit closer is carried away and $1\frac{1}{2}''$ of the metallic conductor exposed, the following readings may be expected.

Sea cell test.		Battery test.	
Zinc.	Copper.	Negative.	Positive.
50 L	26 R	61 23 4	48 18 1

The large reading with zinc and small reading with copper shewn in the first and second columns, indicate that the zinc plate in the circuit closer is disconnected and that some other metal, such as tinned copper or copper, is exposed. The large reading on the 10-coil, in the third column, shews that the resistance of the circuit indicates nearly what is termed dead earth, and the comparatively smaller reading on the 10-coil in the fourth column, when the positive current is applied, shows that the casualty is in the form of a leak; an exposed metallic surface, (that of the conductor), which, acting in connection with the home zinc as a sea cell, assists the negative and opposes the passage of the positive current. All the readings will be occasionally unsteady in consequence of the motion of the loose end of the conductor in the water, and the deposit of the chloride which is continually dissolved and washed off as rapidly as it is formed. With these readings, the shutter of the signalling apparatus would drop.

Readings with main electric cable parted.

In the event of the main electric cable being parted, and the same amount of bare conductor exposed, similar readings would be observed, so that when a defect of this extent exists on the circuit, it cannot be decided whether the charge is disconnected or not. Under any circumstances, as the shutter will not remain up, the main electric cable must be under-run and the mine with its circuit closer examined.

Readings occasioned by a defective or damp joint.

When a defect of insulation occurs in the circuit, of such a nature as would be occasioned by a damp joint, the following readings have been observed.

Sea cell test.		Battery test.	
Zinc.	Copper.	Negative.	Positive.
2 R	57 R	46 12 1	47 7 1

In this case the existence of the fault is indicated by the increased readings on the 10-coil, the readings with the positive current being the smaller of the two. The sea cell test in this instance will be rapidly changed, by depolarizing the line for two minutes, and it cannot be determined whether the circuit closer is gone or not. A fault of this nature might reduce the resistance of the circuit from its original perfect condition even down to 150 ohms, but the shutter, set to a resistance of 60, would not be affected. And such a defect is not of vital importance.

Readings with a clean cut through electric cable

The existence of a defect, exposing so much of the conductor as may be represented by a clean cut through the electric cable, has been observed to give the following readings.

Sea cell test.		Battery test.	
Zinc.	Copper.	Negative.	Positive.
41 L	45 R	52 12 1	46 6 0

As the defect increases, the tests in the first two columns would probably not alter materially, but the readings on the 10-coil, during the battery tests, would become larger, and when they amount to 20 the shutter would fall, and the charge with its cable must be examined.

Practically it has been found, that loss of insulation through the main cable or branches very rarely occurs, except in the case of actual fracture. Any steadily increasing change would therefore probably be due to the fuzes becoming damp, or damp forming a bridge between the line and earth wires in some portion of the circuit inside the charge. This might happen when experimenting with an empty case, but it can be entirely prevented by waterproofing the fuzes, and insulating all the connections inside the case very carefully. With a loaded mine, the damp would, to a great extent, be absorbed by the powder or gun-cotton.

Readings with a fractured cable.

If the cable has parted, the fractured end may be sealed by the insulation closing over it, or the conductor may remain exposed. In the first case, that of a sealed end, there would be an absence of all readings, and in the second, the character of the readings would vary according to the amount of the conductor exposed. If only the end of the conductor is in contact with the water, as in a clean cut, the following readings have been observed.

Sea cell test.		Battery test.	
Zinc.	Copper.	Negative.	Positive.
50 L	18 R	54 11 2	43 6 0

The sea cell tests may be rapidly altered, by depolarizing the line for two minutes, no definite information is therefore obtained, beyond the fact that the resistance of the whole circuit is materially reduced, and that the conductor is exposed. The loss of resistance is most clearly indicated by the increased readings on the 10-coil; the shutter would not, however, drop.

If half an inch of the conductor is exposed, the follow readings have been observed before depolarizing the line.

Sea cell test.		Battery test.	
Zinc.	Copper.	Negative.	Positive.
50 L	26 R	61 23 0	48 18 1

The shutter in this case would fall. It will be observed th the readings, in the case of a fractured cable, only differ i character from those obtained in the case of a defect of insulati from the fact that the deflection in the second column is ab 45 in the latter case, due to the presence of the zinc plate at t circuit closer, while it is reduced to about 26 in the form when the circuit closer and charges are disconnected.

Readings with a wet circuit closer.

In the case of a wet circuit closer, the following readings hav been observed before depolarizing the line.

Sea cell test.		Battery test.	
Zinc.	Copper.	Negative.	Positive.
43 L	41 R	56 10 2	46 10 0
and varying to			
35 L	53 R	59 29 4	49 25 4

The sea cell readings would, in this case, be unsteady. Th readings are very characteristic, and differ from those obtain with a defect of insulation on the line, in the fact that they a the same both with the negative and positive current, and t readings on the 10-coil are not reduced when the positive curr is used. The readings of the battery test would vary great from day to day, in consequence of the disturbance of the wat which has entered the dome of the circuit closer; a "de earth" connection would occasionally be observed and t shutter would fall. It has been noticed that a circuit clo may leak for five or six months without interfering with efficiency. The small quantity of water is of no consequence long as it remains at the bottom of the dome; as soon, howev as the amount is sufficient to make the whole of the interior of t case thoroughly damp, or perhaps actually wet, from the splashi of the water, decided changes in the tests would be observed. T conducting wires, inside the apparatus, are carefully insulated f some distance from the base, and would consequently not b short-circuited by water at the base. If these wires were stripp of their insulation at the point where they leave the base pla within the apparatus, the existence of the smallest quantity water inside would be at once made known, by the water cros circuiting the wires. It is considered an advantage, howev that the apparatus should not necessarily be rendered inoperat by a small amount of leakage. It would save the worki parties much trouble if the fault could be traced to the circ

closer, through the information given by the tests, as it is probable they might be able to get at the circuit closer at low water, in a dingey or cutter, and examine it, without raising the junction box and under-running the electric cable.

Readings with a wet charge.

In the case of a wet charge, the following readings may be expected:—

Sea cell test.		Battery test.	
Zinc.	Copper.	Negative.	Positive.
nil.	46 R	61 23 4	61 23 4

Here, there would be no material change in the sea cell tests, as the zinc guard, inside the charge, being wet would give similar readings to those due to the usual zinc earth connection of the system when everything is correct; the battery tests on the 10-coil shew, however, large readings, equally great with the positive and negative currents, and the shutter would fall.

In the case of a loss of continuity in any part of the main circuit, with perfect insulation, there would be an absence of all readings, and it would be concluded at once, that the conductor was broken within the insulation, the latter not being fractured.

A defect of insulation comparatively unimportant when a platinum wire fuze is used. With a tension fuze it is always a serious consideration.

It must be borne in mind that, with the platinum wire fuze, a very considerable defect in the insulation of the cable, between the fuze and the firing battery, (as much as 24 inches of bare conductor, see pages 95 and 96), does not prevent the charge being fired by the application of a few additional battery cells; while a very small defect, ($\frac{1}{16}$ of an inch for example), in the same position would be fatal to the tension fuze, which could not be fired under such circumstances without a very large increase of battery power. The discovery of the extent of a defect in the insulation is a matter of considerable importance at all times, but especially when a tension fuze is employed. A small defect in insulation beyond the fuze would not be of much importance if a platinum wire fuze, arranged as in the electro-contact system, described at page 159, were used, but with a tension fuze a minute defect in such a position would make a sufficient earth connection to fire the fuze, if the firing battery were put in circuit. It is for this reason that the tension fuze has been combined with the shutter signalling apparatus, by which the firing battery is only thrown into circuit with the fuze of any particular mine to be exploded, at the moment it is required for use. With a platinum wire fuze and circuit-breaking system, a moderately large defect in the insulation of the electric cable, would probably stop the power of signalling by means of the shutter apparatus, but would not prevent the charge beiug fired. With a tension fuze and circuit closing system, a comparatively small defect in the insulation of the cable might not only prevent signalling by means of the shutter apparatus, but if it existed between the firing battery and fuze, would be very likely to

prevent the firing of the charge. The tension fuze adopted for submarine mining service, (No. 6 detonator, electric, Abel, submarine), is less affected by defects of insulation, of the nature mentioned, than the original Abel's mining fuze (No. 1 Fuze, electric, Abel; or No. 5 detonator, electric, Abel).

A defective charge or cable should be at once taken up.

When a defect has been found to exist in any part of a circuit, it should be taken up and repaired with the least possible delay, unless the presence of an enemy or some other imperative cause interfered to prevent it. Although it is most essential that the necessary tests should be made, and the nature of the defect discovered, if possible, without disturbing the mine: still, on service, too much time should not be wasted in trying to discover exactly what has happened. Having ascertained that a charge is defective, it should be put right with the least possible delay. With this object in view, arrangements are made to admit of raising the charge and circuit closer, (or circuit breaker as the case may be), with facility. Should a defect exist in the electric cable it should be under-run, and if it be a defect in insulation, its position may be discovered by keeping a test battery in connection with it during this process, and the moment the defect was lifted out of the water, its position would be indicated by a sudden reduction in the deflection of the galvanometer needle, as described in the test of electric cables, page 281.

Instruments used in electrical testing in connection with testing table.

The following instruments have been combined in the form of Testing Table adopted for service, shewn in *Plate* LXXXI., and described at page 272, viz., the Astatic Galvanometer, Three-coil Galvanometer, Wheatstone's Bridge, combined with a set of Resistance Coils, capable of directly balancing up to 10,000 ohms, Thermo-galvanometer, combined with a set of Resistance Coils suited to a quantity current, such as that of the Walker's Firing Battery, Commutator, Reversing Key, Firing Key, Switch Plates, and Testing Battery. These have been described in connection with the Testing Table. In addition to the above each station should be supplied with one or more common Detector Galvanometers.

Detector galvanometer.

The Detector Galvanometer is generally made with a vertical needle, and is used for all the rougher tests requisite for submarine mines. For this purpose, it should be made as sensitive as possible, commensurate with small size and portable form. An insensitive detector galvanometer is of comparatively little value for the tests employed in connection with submarine mines. An instrument of this nature, sufficiently sensitive for testing purposes, approved for submarine mining service by the Torpedo Committee and adopted, is formed with coils possessing an electrical resistance of about 100 ohms; it is made in a very portable form, suitable for boat service. The three-coil galvanometer may be used as a detector, if required, in the testing room.

Electrical

At certain important stations, electrical tests of a very delicate

nature may be necessary, and, for such purposes, special instruments, such as the Reflecting Electrometer and Reflecting Galvanometer would be required. Instruments of this nature are used by all manufacturers of electric cables, and in order to obtain the full value of the very delicate tests to which they are applicable, special arrangements, of a permanent nature, must be provided in the testing rooms in which they are employed.

instruments for very delicate tests.

Reflecting Electrometer.

The Reflecting Electrometer is a comparatively recent invention of Professor Sir William Thomson, F.R.S. It is an extremely delicate instrument, requires very careful handling, and can only be used by a practised electrician. It is now very extensively used by electric cable manufacturers and others.

Reflecting Galvanometer.

The Reflecting Galvanometer is well known to all electricians, it is an older invention than the reflecting electrometer, and is also due to the genius of Professor Sir William Thomson, F.R.S. It is also an extremely delicate instrument, applicable to very fine tests: it is, however, more easily managed than the Reflecting Electrometer.

Differential Galvanometer.

Another instrument, called the Differential Galvanometer, might be applied for many of the tests employed with a system of submarine mines. It is extensively used in the Government, Post Office, Telegraph Service, and is an extremely useful instrument for electrical purposes. The results obtained with it are very accurate, generally sufficiently so for all purposes connected with submarine mining operations. Two instruments of this nature have been recently devised, viz., Latimer Clark's, Double shunt, Differential Galvanometer, and the Post Office pattern, Differential Galvanometer, the latter designed by Mr. Becker, electrician to Messrs. Elliott, Brothers. The former instrument is extremely portable, and is capable of being used in a great variety of combinations, as described in Mr. Latimer Clark's very excellent hand-book on *Electrical Measurements.* The Post Office pattern instrument is very similar in principle to Latimer Clark's; it differs in having only one shunt, and in being constructed with a suspended needle, instead of one working on a pivot. It is more delicate than the former, only inasmuch as the principle of suspension is a more delicate combination than that of a pivot, other details of construction being similar. It is not so portable as Latimer Clark's instrument, and cannot be used in a boat, or in any position where there is no steady foundation to put it on.

Qualification of officers and men employed.

The Officers, N.-C. officers and men, employed in working any system of submarine mines, must be thoroughly instructed in electricity and further be well up in telegraphy, visual signalling, and in the use and management of boats and mooring apparatus. It has been found that the course of instruction, necessary to qualify thoroughly for this service, occupies a period of about six months. A detachment for work with a system of submarine

Number and constitution of detachment.

mines, should consist of 9 thoroughly-instructed N.-C. officer and men. This may be considered as the unit, and one or mor such detachments would be required according to the extent o the work to be performed. These should always be under th charge of an officer, even if only one detachment is required Every N.-C. officer employed on submarine mining service, shoul be capable of making all the tests and taking entire charge o the testing room, in addition to a thorough knowledge of th other duties. The numbers above given should be distributed i the several boats, &c., as detailed at page 174, and are in additio to the seamen therein enumerated, whose duties would be simply those entailing ordinary manual labour, or those portions of th work, such as mooring, for example, for which their previou experience would especially qualify them.

N.-C. officers and men to be of certain trades.

The N.-C. officers and sappers employed, should be selected from those trades, which would be most useful in connection with the apparatus used for carrying on a system of defence of this nature, such as blacksmiths, fitters, tinsmiths, carpenters, &c. The nature of the apparatus is such, as frequently to require the services of a mechanic acquainted with the above-mentioned trades, and men who are simply instructed in the system, without being tradesmen, would be likely to find difficulties, if any small defects should exist, which they could not themselves repair.

CHAPTER XIV.

Clearing Channels of Submarine Mines.

The best method of clearing a channel defended by submarine mines, though more a naval than a military question, is one concerning which a certain amount of knowledge is requisite for all engaged in the use of machines of this nature.

Use of passive obstructions combined with submarine mines.

Passive obstructions, in the shape of booms, nets, &c., would be used, where possible, to check an enemy's operations against the mines, and to impede boats and small vessels in their approach towards them. In their project for the defence of Venice in 1866, the Austrians proposed to place a light boom, in advance of their outer group of mines, with this object in view, and experiments have recently been made by the Prussians, to test the use of such obstructions in a practical manner.

Mode of clearing channel by small boats followed by larger vessels.

The hostile removal of submarine mines, implies the absence of guard boats and of land defences, or the inability of the latter to see the operation owing to darkness or fog. Where electrical igniting apparatus is suspected, the banks of the river or roadstead should, if possible, be searched with a view to intercept the wires. The advanced booms and nets, if any, would be blown up, or, if secrecy be an object, cut, or turned by boats rowing round their shore ends, Lines of boats might then advance in couples, towing small hawsers, weighted about the centre, between them, with a view to sweep the suspected waters for buoyant mines and circuit closers, their own light draught giving them sufficient immunity. When a submarine mine or circuit closer was thus caught, a signal would be made to other boats to avoid the locality, whilst the two boats concerned, crossing the ends of their hawser, would cautiously pull the mine up to the end of a long outrigger, (or davit), and carefully cutting the mooring rope, tow the mine into shallow water. Other lines of boats might follow, dragging small grapnels, in the hope of intercepting the wires of such ground mines as were unprovided with circuit

closers. The channel being thus partially cleared, small steam vessels might advance in pairs, dragging between them larger hawsers, weighted with chains and armed with grapnels; whilst pushing some sixty feet before each vessel a submerged framework, armed with hooks and nets, extending below the keel and beyond the broadsides, which might intercept and explode harmlessly the usual mechanical submarine mines. Even with very slow speed and every precaution, great danger would be incurred for the steam vessels in the case of circuit closers attached to ground mines, as the former might be dragged forward by the projecting frame, and close the circuit when its mine was actually under the bottom of the ship. The breadth of channel so cleared should be carefully marked, to prevent advancing vessels passing over unsearched ground. It is obvious that such operations could only be undertaken, in undefended and unguarded waters. And it is worthy of remark, that most of the United States vessels destroyed by submarine mines, were lost whilst advancing in waters previously dragged or otherwise examined by boats. The introduction of electrical apparatus increases the difficulty of clearing channels, and too much precaution cannot be observed in navigating waters which are supposed to have been defended by submarine mines, even after they have been most carefully searched. If advanced booms or nets are not used by the defence, barges or rafts, with submerged frames to give deep draught, might be employed to drift over the suspected waters, with a view of exploding the mines by contact, should the conformation of the river or roadstead admit of it. If the tidal stream be very strong, light grapnels might be dragged over the bottom by these drifters, with a view of fouling the electric cables or mooring ropes, should the nature of the ground favour the proceeding. It is evident that a rough or rocky bottom, or the employment, by the defence, of a heavy chain laid across the channel in advance of the mines on hard ground, might convert the grapnels into anchors, and thus defeat the primary object of exploding self-acting mechanical mines by contact. In many places, in the Medway for example, a heavy chain would soon sink into the mud, and become so far covered as to offer a small chance of catching the grapnel: under the same conditions, however, the electric cables would equally sink into the bottom, and be less likely to be fouled.

Projecting frames or nets carried in advance of a vessel's bows.

In their operations against the Confederates, the Federal fleets in many cases used projecting frames and nets, in front of the bows of the leading vessels, in which the submarine mines, arranged for mechanical ignition, were intended to be caught without danger to the ships. Notwithstanding this precaution several vessels were sunk and damaged. In many cases, the charges were not fired at all, but this was due more to the failure of the igniting apparatus than to any special value attaching to

the mode in which the machines themselves were caught: with the more efficient means we now possess for firing mechanical mines, combined with the vastly increased size of the charges proposed to be employed, it is probable that this mode of clearing a channel would be a far more dangerous and difficult operation; a mine would be fired with far greater certainty, and its radius of destructive effect would be so much increased as to necessitate a frame, extending to a much greater distance in front of a vessel, than those used in the operations alluded to.

In the case of mines fired by electrical agency, the danger to a vessel using a projecting fender would be still greater, if circuit closers in connection with ground mines were to be attacked. In such a case the circuit closer only would be caught by the fender, and the vessel would be more or less over the actual mine, when the collision, with its consequent explosion, would take place.

Fenders of this nature should, in all cases, be constructed to extend to as great a depth as possible below the water level, so as to catch mines and circuit closers not only near the surface, but to a considerable depth below it.

Solid ship for clearing a channel.

One mode, which has been suggested for clearing a channel, is to construct a vessel of timber, entirely solid, like a raft, and propelled by steam power. Such a vessel would be unsinkable. She might be sent in advance, through a system of submarine mines, followed closely by another vessel, drawing less water, by which latter the channel, through which she had passed, would be buoyed. She might be steered in the usual way by a small crew actually on board, or at the most critical moment of the operation, her crew might be removed and she might be steered electrically from the vessel following her closely. If she came in contact with a mine, it would be exploded without sinking her and she would probably continue her course without serious interruption. Such a vessel should be of considerable length, so that an explosion against her bow might be kept well away from the engines, which should be placed as far aft as possible; her draft of water should be considerable, so as to catch mines at the greatest depth at which they would be likely to be encountered, and her breadth should be increased by outriggers or fenders, or some such devices, so as to sweep as wide a channel as possible. The construction and management of such a ship might or might not be practicable; the idea, however, seems worthy of consideration.

Cable paid out from electrically-steered steam launch.

Another mode, which has been suggested, is to pay out a chain cable, so as to include a certain area, by means of an electrically-steered steam launch, and having got hold of the two ends, to haul on them and thus drag over any mines that might be included within the space enclosed. A grapnel might be laid out by this method, in such a position as to be capable of being dragged over ground where electric cables might be expected to exist. Rogers'

projectile anchors, or something on the same principal, have al-
been suggested: these can be thrown out to a distance of abo-
130 yards.

Mode of attack suggested by Lieut. W. H. Hall, R. N.

The following mode of attack, has been suggested by Lie-
W. H. Hall, R.N. Should it be desired to render a channel
for the passage of a fleet, for a temporary purpose only,
not with a view to the permanent occupation of the place, a-
instance, to bombard and destroy a dockyard, it is sugge-
that the mines be rendered innocuous, for a time sufficient
accomplish this object, in the following manner:—

Let a feint be made on the side of the channel farthest fr-
the station, into which it is supposed the conducting wires fr-
the mines are led, by sending boats in to explode some cha-
as if with the intention of clearing the channel. This w-
attract the attention of the enemy's guard boats, and prob-
draw them away from their posts. At the same time, send
two detachments of boats, along the opposite side of the chan-
with orders to one detachment to make for, get hold of a-
cut the connecting wires between the two stations, and to th-
other to get hold of and cut the electric cables leading from th-
mines into the firing station. For this purpose, a portion
the boats of each detachment should be provided with grap-
and axes, and the remainder should act as a guard to keep
and destroy the enemy's boats, should they discover them.
attacked, running should be resorted to, no firing being allowe-
in order to prevent an alarm which would cause reinforcem-
to be sent to the point attacked. Should a cable be got hold
it should be cut, under-run for about 100 yards, and cut ag-
and the piece cut out towed away, or if time does not perm-
this, when cut, the end should be towed away some distance fr-
its other part before being let go. The mines will then be harm-
until the ends of the cables have been got hold of, towed toget-
(if there is slack enough), and connected, or fresh cables la-
down: a work in either case, requiring considerable time. It
not absolutely necessary, for this purpose, that the connect-
cables between the stations be cut; but the attempt to do th-
will, if successful, further derange the enemy's system, and w-
at all events, help to draw attention off the other detachm-

The above ideas are put chiefly in the form of suggest-
Little or nothing has been done, in the way of experiment, or
perfecting any system for clearing a hostile channel studded wi-
submarine mines. The subject does not seem to have recei-
that attention from our naval authorities which it unquestionabl-
deserves: a great deal remains to be done in this direction, be-
our ideas, on the subject of clearing channels, advance beyo-
the point which they have now attained, and which can only
compared to groping in the dark.

The course adopted by the Federal fleets, in searching chann-

for submarine mines, was first to send forward boats to sweep for them, and to follow the boats up with vessels fitted with fenders of the nature described. This system seems to be that best calculated to ensure success, as far as our present practical knowledge is concerned.

Suggestion for the use of twin mortars, fired simultaneously, in searching for mines.

The following mode of operation, which may or may not be capable of practical employment, is suggested for the consideration of Naval and Artillery authorities. It consists in simultaneously firing, by electricity, a couple of mortars, pointed in such a manner as to cause the shells to diverge from each other, using very small charges of powder, only just sufficient to give a range of 400 or 500 feet, and having previously attached a chain to each of the shells, and another connecting the two shells together, the effect would be to cast the chains out and inclose a certain area. By hauling on the two extremities of these chains, any mine within that area would be caught, and probably injured or destroyed. In certain parts of the world, Bermuda for example, the sea water is so extremely clear that, in fine weather, such an object as a submarine mine would be easily distinguishable from a vessel's tops, at a considerable distance and at a great depth: in such a case this mode of clearing a channel, by throwing out a chain attached to a couple of shells, might possibly be successfully employed. Very clear water would be a favourable condition, as regards the search for submarine mines, whatever mode of proceeding may be adopted.

In this, as in all operations of a similar nature, the same difficulties, as regards interruption caused by the fire of guns defending the system of mines, would still exist.

To be effective, it is probable that a specially fitted vessel and a special crew would be required. Such an operation would be comparatively easy if the mortars were fired from the shore or from a vessel anchored in a harbour in smooth water, but it must be borne in mind that, to be effective, it should be capable of being used in moderately rough water and from a vessel not necessarily at anchor.

Clearing a channel by submarine explosions.

Another method, which has suggested itself in the course of experiments carried on at the School of Military Engineering, Chatham, during the Autumn of 1870, is to fire large charges of gun-cotton in positions which are supposed to be studded with submarine mines, with a view to destroying any charges which may be within the radius of explosive effect: to proceed, in point of fact, on the same principles which have been found effectual in attacking a land fortress defended by countermines. The experiments made demonstrated satisfactorily, that a charge of 432lbs. of gun-cotton, fired under a head of between 40 and 50 feet of water, destroyed and rendered ineffective a series of mines placed in its vicinity, to a radical distance of at least 120 feet*

* The cases of these mines were, however, only $\frac{3}{16}$ of an inch thick. Those of ground mines, provided for use at a similar depth, are of $\frac{1}{4}$-inch iron.

from the point of explosion. It would not be difficult nor tedious, with a little previous preparation, to carry on a series of explosions of charges of 500lbs of gun-cotton. They might be easily manœuvred and fired from an ordinary steam launch, and two or three of these boats moving abreast, firing their charges, and gradually advancing over the ground thus made good, would in time clear a channel, sufficiently wide to admit of the safe passage of the largest ironclad. During such an operation, these boats would no doubt be fired on by the guns covering the mines, and it would be absolutely necessary to cover them to the utmost extent, by the guns of the attacking force. The night, or foggy weather, would be the most favourable time for operations of this nature.

A slow speed to be employed by vessels searching a channel.

In whatever way a boat or vessel may be employed in searching for submarine mines, or whatever may be her size, it is of the utmost importance that she should move as slowly as possible, in fact with the least possible speed commensurate with efficient steerage way. In moving at a slow speed, she would be less likely to explode a charge by contact, and would be more easily checked if found to be getting into danger.

The clearing of a channel, defended by submarine mines would under any circumstances be a tedious and dangerous operation, and the delay thus incurred could not fail to be of immense advantage to the defence, even if every ship and boat in the enemy's fleet escaped injury.

CHAPTER XV.

Locomotive Torpedoes.

We now come to the locomotive class of apparatus for producing submarine explosions, adapted for use in offensive warfare. These are more especially a Naval arm, and to them the term Torpedo is properly applicable. They may be divided into three classes:

Outrigger torpedoes. 1st.—Those to which motion is given by a ship or boat to which they are attached, and from which they are manœuvred.

Projectile torpedoes. 2nd.—Projectile Torpedoes, or those possessing in themselves the power to move through the water, when once started, in any particular direction.

Drifting torpedoes. And 3rd.—Drifting Torpedoes, or those dependent for their motion on the tide or current of a stream. All three classes are applicable generally for the attack of vessels, at anchor or in motion, as well as of booms or obstructions of any sort, pontoon bridges, etc.; some forms may be most effectually used against stationary, and others against moving objects to be attacked.

To the first class belong those projected from a boat or ship by means of a spar or outrigger, as well as Harvey's towing torpedo, and all similar contrivances.

To the second class belong those propelled by compressed air, as Lupin and Whitehead's torpedo; those to which motion is given by means of rocket composition, as suggested by Mr. Lancaster, the gunmaker, and Mr. Quick, Engineer, Royal Navy; that recently suggested by Col. Von Scheliha, propelled by compressed air, and steered by electrical apparatus; and all similar devices, in which the motive power is self-contained.

To the third or drifting class, belong M'Evoy's torpedo, Lewis's torpedo, and those of a similar nature.

Special outrigger torpedo boats employed by the Confederates. The idea of attacking vessels by means of boats, either specially constructed for the purpose, or with the apparatus adapted to existing forms, appears to have originated with Fulton, in 1803; it was, however, considerably developed and brought into a practical working form during the late civil war in America.

The Confederates made and used several special boats, some propelled by steam, or by a screw propeller worked by manual labour, to carry a torpedo attached to a spar or projection in front, to be exploded in contact, or nearly so, with the hull of the

vessel to be attacked. The specially constructed boats were provided with water-tight compartments, and when some of these were filled, the whole was so far submerged as to show but very little above the surface of the water. The general results obtained with them were unsatisfactory; they were very dangerous to navigate in a sea, and one, which had already sunk four times, drowning four crews, finally went down with a fifth crew in destroying the United States corvette, "Housatonic," off Charlestown, South Carolina, on the night of the 17th of February, 1864. The corvette was sunk, but nothing was ever again heard of the torpedo boat. This was the only successful attack, out of five attempts made by the Confederates with boats of this nature, and the results were so discouraging that they turned their attention to the use of ordinary ship's boats for this service.

Results obtained unsatisfactory.

Outrigger torpedoes fitted to ships and boats of ordinary construction.

The results as regards ship's boats carrying torpedoes on outriggers or spars, to be pushed out and fired in close proximimity to a vessel's hull, were more satisfactory. Several steam launches were adapted for service in this way, by both Federals and Confederates. Their general arrangements consisted of one or more long spars, to the extremities of each of which a torpedo was attached, carried in such a way as to be readily pushed out from the bow of the boat, immediately before the absolute moment of attack, the charge being fired by the percussion of a self-acting mechanical fuze on the hull of the enemy's vessel, or by means of an arrangement in connection with a trigger line; this latter combination was generally employed by the Federals. The Confederate torpedo boat, "Spuib," which attacked, and so seriously damaged the United States' frigate, "Minnesota," lying at anchor in Newport News, at 2 a.m. on the morning of the 9th of April, 1864, was a steam launch fitted in this way: a very good account of this operation is given in Captain Harding Stewart's *Notes on Submarine Mines*. The torpedo boat, with which Lieut. Cushing, of the United States Navy, successfully attacked and destroyed the Confederate Ram "Albemarle," which was, at the time, alongside the wharf at Plymouth, eight miles above the mouth of the Roanoke river, and carefully protected by a strong timber boom and other obstructions, was an ordinary man-of-war's steam launch: a good account of this very daring enterprise, which was carried out at 3 a.m. on the 28th of October, 1864, is given in a book entitled *Submarine Warfare, Offensive and Defensive*, by Commander Barnes, United States Navy, page 142. In this latter work, at page 154, there is also a very good account of the United States torpedo vessel "Spuyten Duyvil," of 200 tons, specially designed for use with an outrigger torpedo, to be pushed out, below her water line, through a watertight opening in her bow. This vesssel seems to be very completely fitted up, but no opportunity has occurred of trying her against an enemy's ship. The construction and general arrangements of the

Results obtained more satisfactory.

"Spuyten Duyvil," were condemned by the *Floating Obstruction Committee*, as may be seen from the following extract from their report, page 138:—"In the beginning of 1865, the plans of Mr. Wood's outrigger torpedo apparatus were offered to H. M. Government, but a careful examination confirmed the opinion originally entertained as to the too complicated nature of the machinery. The arrangement for giving lateral motion to the outrigger is obviously unnecessary, inasmuch as this may be accomplished by the use of the helm; it is also dangerous, because it renders the outrigger liable to get across the stem at high speeds, when the spar might snap, the torpedo being thus brought under the bottom. The separation of the torpedo from the outrigger before exploding, as proposed, would involve the danger to the operating ship of advancing within the sphere of its destructive action when the explosion takes place. The Committee therefore fully concur in the opinion expressed by Rear-Admiral A. Cooper Key, C.B., then Captain of H.M.S. 'Excellent,' that this plan 'is not worth adoption, or even of trial with a view to adoption, in our Navy.'" In addition to this vessel the United States possessed a number of steam launches, each carrying one 12-pounder boat howitzer and a crew of 15 men, fitted for outrigger torpedo service, the torpedoes being carried on spars resting on crutches, and ready to be run out and fired at short notice. Six low freeboard monitors were also similarly fitted. The "Spuyten Duyvil" must not be taken as the type of torpedo vessel, which would now be used by the American Navy for war purposes. They seem lately to have turned their attention most zealously to this very important question, and are said to have recently built at least one much more efficient and formidable vessel.

"Spuyten Duyvil" construction disapproved by Floating Obstruction Committee.

No vessel of the class represented by the "Spuyten Duyvil," has ever been constructed in this country, but recent experiments with Lupin and Whitehead's Torpedoes have given such satisfactory results, that a vessel, specially designed for this form of weapon, is now in course of construction at Woolwich, with a view to testing it in a more definite and conclusive manner. A description of Lupin and Whitehead's Torpedo will be given hereafter.

Vessel for use with Lupin and Whitehead's torpedo.

The following observations, on the subject of Outrigger Torpedoes, are extracted from the *Report of the Floating Obstruction Committee*, published in 1868.

"The success which appears to have attended the use of torpedoes as a means of attack by the Americans, led the Committee, at an early stage of their labours, to devote considerable attention to the plans which were submitted for their consideration by Captain H. H. Doty and others, for projecting torpedoes from the bows of small steam vessels by means of outrigger fittings.

Outrigger torpedoes.

"The plans suggested for the arrangement of outrigger torpedo steam ships, among which the most efficient appears to be that proposed by Captain Doty, all involve the application of special machinery and fittings for the vessel, of more or less complicated and costly character, and it appeared to the Committee, upon a careful consideration of the subject, that the objects for which the various mechanical appliances were designed, could be sufficiently attained by easily extemporised devices of a comparatively very simple nature, readily adaptable to the many varieties of small vessels propelled by steam which are now constantly employed in all ports and rivers frequented by shipping.

Fittings suggested by the Committee.

"In March, 1865, the Committee submitted to the Secretary of State for War, plans for applying extemporised outrigger fittings to small steam vessels, and since that time they have endeavoured to ascertain experimentally, with the assistance of the Captain of H.M.S. "Excellent," at Portsmouth, whether any obstacles presented themselves to the rapid application and ready manipulation of such outrigger fittings. Another object of their experiments has been to ascertain whether a torpedo containing a charge of gunpowder or gun-cotton, calculated to produce seriously destructive effects when exploded in close proximity to a ship's bottom, could be fired from a small vessel, such as a steam launch, if attached to the end of an outrigger spar, without risk of injury to the attacking vessel and crew. The conclusions which the Committee believe they are warranted in drawing from these experiments are as follows:—

"(1).—100lbs. of gunpowder, enclosed in a sufficiently strong case for the proper development of its destructive action, can be manipulated with sufficient ease when attached to the end of a spar, projected 25 feet from the bows of a steam launch, and fitted with the gear, described at page 139, and *Plate* XXXVIII., page 144.*

"(2).—A charge of 25lbs. of compressed gun-cotton, which may be relied upon to produce a destructive effect equal to that of 100lbs. of powder, furnishes a considerably lighter and less bulky torpedo than the latter, and is therefore decidedly the most convenient for boat service.

"(3).—Either of the above charges may be exploded from a steam launch, with safety to its crew and engine, if submerged at a depth of 10 feet below the surface, and fired at a horizontal distance of 20 feet from the launch. For this purpose the outrigger spar should project about 23 feet from the vessel.

"Some experiments are still needed for the purpose of determining whether, when the torpedo has been lowered and the outrigger spar fixed at the proper angle, the launch may be navigated over a moderate distance of water without difficulty.

* These pages and plate refer to those of the "Report of the Floating Obstruction Committee." It will be described hereafter.

"Captain A. W. A. Hood, R.N., of H.M.S. "Excellent," has instituted some additional instructive experiments for the purpose of ascertaining whether much smaller craft, such for example, as gigs or whale boats, can be safely and effectively applied as outrigger torpedo boats, and the conclusion to which he has been led is, that charges exceeding 40lbs. of powder, submerged at a depth of 10 feet, cannot be exploded with safety from a 30 feet gig at a horizontal distance of 14 feet. *Experiments with gigs and whale boats, by Capt. Hood.*

"Though a 40lb. charge exploded at such a depth of immersion might prove effective if in absolute contact with a ship, yet the Committee are of opinion that the uncertainty which would attend the attempt to secure such contact in the various contingencies of actual service, must inevitably lead to failures, as it repeatedly did in the American experience. For this reason they consider that 100lbs. of gunpowder, or its equivalent in gun-cotton, is the least charge that should be employed. The explosion of such serviceable charges, within a horizontal distance of 14 feet from the operating boat, was never contemplated by the Committee, but it is evident that these charges may be exploded with safety from any ship of war's boat capable of projecting a torpedo at the extremity of an outrigger, to a horizontal distance of not less than 20 feet. *Size of charge for service.*

"Captain Hood has devised a very convenient arrangement for handling outriggers in small boats, which has the advantage of enabling a second torpedo to be brought very readily into action. Though no explosions have been made with 100lb. charges attached to this apparatus from boats smaller than a launch, the committee have reason to believe that it can be easily adapted for employment with such torpedoes, projected by outriggers of suitable length, from most of the boats carried by ships of war. In determining, therefore, the class of boat to which the outrigger apparatus should be fitted, it will only be necessary to select that which is best adapted for this service by its ability to carry the outrigger with ease, its speed and handiness, and by such other qualities as may be most suitable to the particular time and place of attack, whether it be by day or night, in a harbour or river, or in the open sea. *Rigging-out apparatus.*

"The implements and manipulations connected with the explosion of outrigger torpedoes, need only be of the most simple kind. Many plans have come to the notice of the Committee for exploding this class of torpedoes by mechanical agency; thus it has been proposed to apply friction tubes to their explosion, a method of firing which embraces several elements of uncertainty; various mechanical arrangements (some of which appear to have been used by the Americans), to be fitted into the heads of the torpedoes, and to explode upon collision with the ship's side, have also been suggested, that of Mr. C. A. McEvoy being decidedly the best *Simplicity in manipulation essential.*

of this class of contrivances, but the Committee consider that any mechanical arrangement for explosion by a blow must involve elements of danger or uncertainty—either the torpedo is liable to accidental explosion from a blow or fall in the course of the manipulation to be performed after the "exploder" has been fixed into it, or the latter must be provided with a safety guard, the removal of which at the last moment may be neglected, moreover the employment of such an arrangement would necessarily limit the direction from which a ship could be attacked with a prospect of success.

Simplicity in voltaic arrange- essential.

"The great simplicity to which the Voltaic arrangements, required for boat service, have been reduced by the experiments conducted at Woolwich during last year under Mr. Abel's direction has placed beyond doubt the advisability of exploding outrigger torpedoes exclusively by electrical agency. The simple pile battery, which is readily constructed and put into working order by seamen after a very brief instruction, is prepared from materials everywhere at hand, has no special fittings whatever, remains in continuous working order for at least 24 hours, and may be used in open boats in any weather. A small length of covered wire is all that is specially required in addition to this battery and the electric fuzes, for exploding the torpedoes, and even the coated wire and fuzes, suitable for this simple boat equipment, may be extemporized on board ship. The only operation to be performed by the man in charge of the boat battery, in order to explode the torpedo upon receipt of the word of command, is to touch a metal plate on the battery with the end of the conducting wire which he holds in his hand; but if it be desired to render the firing of the torpedo quite independent of any operator, and also to ensure its explosion at the instant of its collision with the ship's side, it should be fitted with the electrical percussion fuze, devised for that purpose by Mr. Abel. This fuze, which is perfectly harmless unless placed in an electric circuit, may be fitted to the torpedoes either in the boat or previously to their being placed on board. Just before the torpedo is lowered into the water, or before the outrigger is projected from the bows, one end of a conducting wire is screwed into the fuze; as the boat approaches the vessel to be attacked the other end of this conducting wire is attached to the battery (which is already connected to earth), and the torpedo is then ready to be fired by collision with the ship.

"The Committee entertain a strong opinion that the simple system of applying torpedoes by means of outriggers, referred to in the preceding paragraphs, if carried out by men well trained in the management of the outrigger boat and its fittings, under cover of the night, is likely to prove a most formidable means of attack.

Experiments to test apparatus

"It was deemed proper, however, to submit to actual experiment an expedient of this kind, suitable for the use of boats of ships of war; and on the 15th May, 1866, a trial was made by the Officer

of H.M.S. "Excellent," in concert with the Committee. A small spar was inclined over the stem of the launch, so that the charge at its extremity was at the horizontal distance of 23 feet from the boat, and 6 feet below the surface of the water. The charge was enclosed in a $\frac{1}{8}$-inch wrought iron case, and consisted of 9lbs. 10oz. of gun-cotton, which is equivalent to about 40lbs. of gunpowder. The boat was placed only 6 to 8 feet from, and holding the charge nearly in contact with, the bow of the "America" Frigate: ignition was effected by electricity. The explosion tore away 15 feet of the ship's outer planking, laying bare 11 timbers, starting back an iron knee and an inner plank, and showing daylight through the bottom, the oblique thickness of which, at that spot, was 30 inches. The launch, however, did not suffer in the least; the outrigger was broken 6 feet from the charge, where an iron rod, bearing the torpedo, had been lashed, but the three or four turns of spun yarn, employed as a slight lashing to retain the spar in position, remained undisturbed, showing that no strain had been experienced by the boat.

"To test the probable effect on the operating vessel more thoroughly, a second experiment was made, in which the launch was placed with the outrigger at right angles to, and the charge in contact with the sunken "America," so that the boat might receive the full shock of the recoil due to the explosion. The charge consisted of 74lbs. of gunpowder enclosed in a strengthened barricoe, ignition being effected by a friction tube. The horizontal distance of the charge from the boat was 19 feet $8\frac{1}{2}$ inches, and its depth below the surface was increased to 11 feet. The explosion did not in any way effect the boat, or the lashings and guys of the outrigger, but the outer end of the spar was broken off at a weak point about 8 feet from the charge.

"On the 4th April, 1867, a further experiment was made against the sunken frigate "America," with a launch fitted with an outrigger torpedo. The only special fitting made for the boat was a moveable iron crutch on the stem-head, to receive a spar 6 inches in diameter, and of 30 feet in length. The inner end of the spar had an iron hoop with three eyes for small heel tackles; the outer end had hooped on it a 4-foot rod of round iron, $1\frac{1}{8}$ inches in diameter, to which the torpedo was attached; when required for use the crutch was fastened on the stem, and the outrigger launched through it, leaving 6 or 8 feet of the spar inboard. The outrigger was inclined at such an angle as submerged the torpedo about 10 feet beneath the surface, and 13 feet 9 inches to 17 feet 6 inches horizontally from the boat at the water line, and was confined in this position by three small heel tackles inboard, and externally by a martingale. Charges of 50lbs. and 100lbs. of gunpowder, and 21lbs. of compressed gun-cotton, which is equivalent to about 80 lbs. of gunpowder, were employed; these were confined in wrought iron cases $\frac{1}{4}$ inch thick, and were exploded by electricity. The

boat was in each case secured in position, with the outrigger at right angles with, and a few feet from, the bottom of the sunken ship. At each explosion the spar was broken off at a weak point from 6 to $13\frac{1}{2}$ feet from the outer end, but when the torpedo was projected to a suitable distance from the stem, no injury whatever was sustained by the boat or its fittings, and only a small quantity of water was shipped. On the 20th December, 1867, these results were confirmed by the explosion of a 100lb. charge immersed 10 feet, and projected by an outrigger, in a line with the keel, from the side of the bow of a steam launch, to a horizontal distance of 23 feet 10 inches from the stem at the water line; no injury whatever being sustained by the boat or the machinery.

Results of explosions of 100lbs. of powder at various depths and distances.

"To determine the limits of the destructive results to be anticipated from similar charges exploded at increased depths of immersion, two 100lb. gunpowder torpedoes, were in July, 18[illegible] fired from outriggers projected from a launch to a depth of [illegible] feet, at a horizontal distance from the stem at the water line of 22 feet 4 inches and 17 feet 6 inches respectively. In neither case was the launch injured, though sufficient water fell inboard from the column thrown up by the nearer explosion to have swamped the boat, had not the fore part been protected by a sloping canvas cover, which extended to 15 feet abaft the stem. The depth of greatest effect of 100lbs. charges is estimated to be less than 15 feet, and the lateral destructive action of a serious nature to be anticipated is computed to extend over an area of $9\frac{1}{4}$ feet radius; but it is supposed that a minor destructive effect may extend beyond that distance sufficient to do injury to boats. These experiments tend to confirm the previous estimations of the limited extent of the destructive area, whilst they show that the falling water must also be taken into consideration, in determining the maximum distance at which torpedoes can be exploded from open boats with safety to the operators.

Sizes of boats most suitable for outrigger torpedo service.

"With a view to the application of outrigger torpedoes to the smaller boats of ships of war, a series of experiments were conducted with a 27 foot whale boat, and a 30 foot gig, fitted with outriggers projecting from the broad part of their bows. These side outriggers were found very convenient for carrying and handling torpedoes in light boats, the weight being thrown further aft, and the outriggers being manipulated, without any movement of the crew, by persons in the stern sheets. A canvas awning was stretched over the fore part of the boat to deflect any falling water raised by the explosion. The ignition was in all cases effected by electricity. The length of the outriggers employed in these experiments, did not admit of the explosion of the torpedo at a greater horizontal distance than 15 feet $1\frac{1}{4}$ inches which, with an immersion of 9 feet, was found inadequate to the safety of the boat and crew with a greater charge than 40lbs. of gunpowder. Though this charge would suffice for the destruction

of a ship of war, if exploded in absolute contact, the difficulties of ensuring this on actual service, would render it inexpedient to risk undecided results by the employment of such a doubtful charge. If four-oared gigs cannot be fitted to carry outriggers capable of projecting 100lb. torpedoes to a horizontal distance of 20 feet, their application to torpedo service must be very limited. The means, however, devised for carrying side outriggers in gigs, are equally applicable to galleys and cutters, and there is no reason why these boats should not project serviceable charges to safe distances.

"These experiments show, that outrigger torpedo appliances, to project destructive charges, can be employed in any ordinary ship's boat capable of carrying a spar of sufficient length, with perfect safety to the boat and crew.

"A series of torpedo boat experiments was therefore conducted by the Officers of H.M.S. "Excellent," at the suggestion of the Committee. By these it was demonstrated that 100lbs. of gunpowder, and 21lbs. of gun-cotton can be exploded, with perfect safety to the boat and crew, from the extremity of an outrigger projected from the bow, at such an angle that, when the charge is immersed 10 feet beneath the surface, its horizontal distance from the stem at the water line shall be 20 feet. A charge of 40lbs. of gunpowder, immersed $10\frac{1}{2}$ feet, was also exploded with safety from a four-oared gig with the crew embarked, at the horizontal distance of 14 feet; but a 50lb. charge immersed 9 feet, and exploded at a horizontal distance of 15 feet $1\frac{1}{4}$ inches from a whale boat, swamped the boat. These distances are much less than were at any time contemplated by the Committee as calculated to secure immunity to the operating vessel; whilst the uncertainty of securing, in actual warfare, the absolute contact essential to the destruction of an enemy's ship by the explosion of such small charges, must preclude their employment on service.

"The Committee are of opinion, that outriggers, sufficiently long to project 100lb. charges to a horizontal distance of 20 feet, may be carried in boats of much smaller capacity than launches; but whether fittings can be applied to four-oared gigs, by which they can do so, is yet a matter for experiment. The best means of projecting outriggers from steam ships of various sizes, and of maintaining them in position at different speeds, and their influence on the steering capabilities of the vessels, are problems which have yet to be submitted to experimental investigation."

Fittings of Torpedo boats, as used by H.M.S. "Excellent."

The following description extracted from a book entitled *A Treatise on Electricity, and the Construction and Management of Electrical and Mechanical Torpedoes*, by Commander Fisher, R.N., late Instructor in Electricity and Torpedoes on board H.M.S. "Excellent," gives a good idea of the arrangements proposed in our service for the purpose required.

"A general description will be given of the manner in which a steam launch and gig are fitted in H.M.S. "Excellent" for torpedo purposes, as shewn in *Plate* LXXXVII., both giving most successful results.

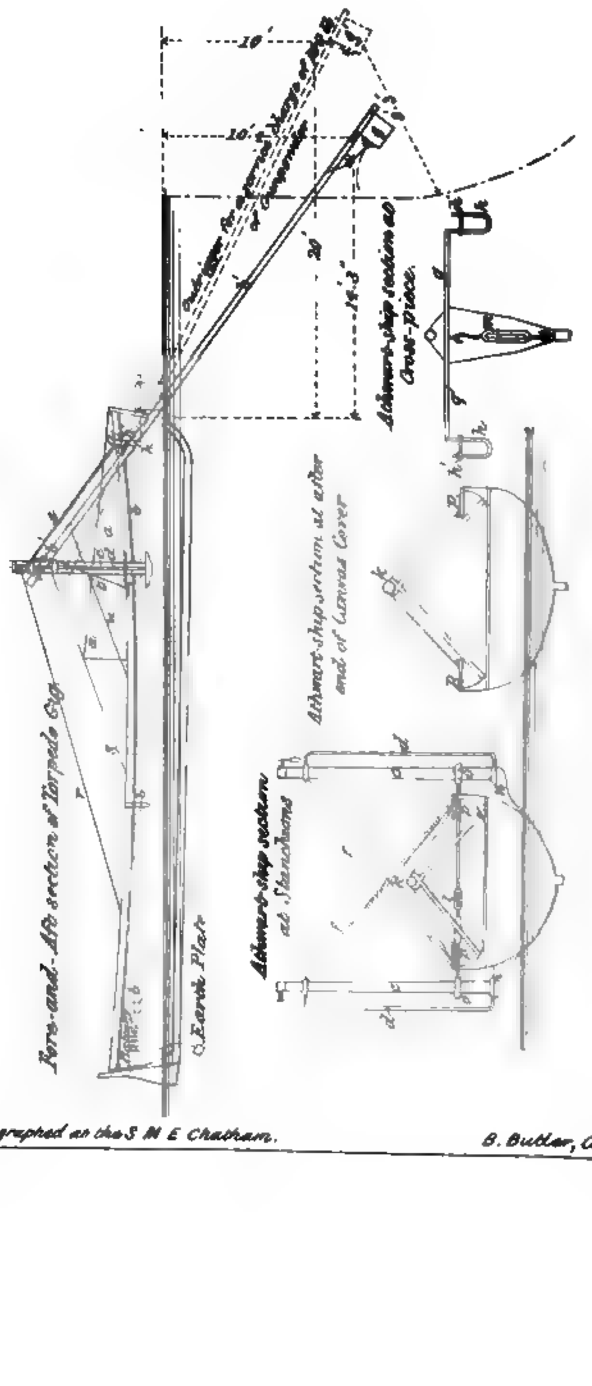
"The fore part of the boat is covered over with a canopy, which is spread over a fore and aft pole, resting on two wooden crutches, and is tightly laced down to a footboard that extends round this part of the boat, just inside the gunwale, to allow the crew to work outside when required. At about two feet abaft the stem a projecting cross piece is secured to both gunwales, having at either end an iron crutch, in which rests the outer part of the torpedo pole when not in use, and which serves as a fulcrum for the pole when rigged out; a pin across the crutch prevents any chance of the pole being lifted out of it. An upright, similar to a rocket stanchion, ships into a step on either side of the boat, outside the gunwale, and is secured to it by iron clamps; these stanchions, which are about six feet in length, have attached to, and projecting from, their exterior sides, an iron rod, the torpedo pole working between the iron rod and the stanchion, so that when the heel of the torpedo pole is triced up to the head of the stanchion, (thus rigging it out and at the same time submerging its outer extremity), the pole is confined between them, and thus any lateral movement is prevented.

"The rigging-out rope of the torpedo pole is led from the stern sheets, through a small block at the head of the stanchion, and made fast to the pole about a foot from the heel. A back rope is secured to the heel, for the purpose of easing out the pole, and of rigging it in again when required. When the poles are rigged in, their heels rest on crutches on the outside of the afterpart of the boat. The height of the stanchion, its distance from the fulcrum crutch, and the length of the pole, depend on the depth to which the torpedo is required to be submerged and on its charge; but appended are the dimensions of the "Excellent's" torpedo gig and fittings, constructed to admit of 40lbs. of gunpowder, submerged nine feet, being fired with perfect safety to the boat and its crew. Such a charge so placed, we know from experiment, would inflict irreparable damage on any ship as at present constructed, if exploded in contact with her bottom*; and as it is probable that the horizontal section of its ellipsoid of destruction at the depth of nine feet, would not be less than a circle of five feet radius, great mischief would doubtless be caused by it even when not exploded in perfect contact, but within the assumed five feet limit.

* This is a statement which, though true as regards wooden vessels, requires confirmation with reference to the strong double bottom of an iron clad: no experiments have as yet been tried to test the result against these latter structures, though repeatedly recommended by various committees,

PLATE LXXXVII.

OUTRIGGER TORPEDO BOAT.



Lithographed at the S M E Chatham.

B. Butler, Corpl R. E

Dimensions of fittings of "Excellent's" steam launch and gig.

"The "Excellent's" steam launch, fitted up in a similar manner, carried a torpedo charged with 100lbs. of fine-grained powder, the only exceptions to the torpedo gig arrangements being that it was submerged to a depth of 10 feet, and the torpedo, when in position, was 25 feet, (instead of $17\frac{1}{2}$ feet), from the stem, in the direction of the pole. No water was shipped on the explosion being effected, nor was there the slightest inconvenience of any sort experienced.

Dimensions of Torpedo Gig and Fittings.

Length of boat	30 feet.
Beam	$5\frac{1}{2}$ feet.
Length of canopy	$10\frac{3}{4}$ feet.
Distance of crosspiece from stem ...	2 feet.
Length of poles	28 feet.
Thickness of butt end of poles	$4\frac{1}{2}$ inches.
Length of stanchion	6 feet.
Distance from stanchion to the crosspiece in stem	5 feet.
Distance from after crutch to stanchion ...	$10\frac{3}{4}$ feet.

"Each stanchion is supported by two $\frac{5}{8}$-inch iron stays, one going to the opposite gunwale and the other supporting it in a fore and aft direction."

Rear Admiral A. Cooper Key, C.B., F.R.S., then Director General of Naval Ordnance, remarked upon the above apparatus and experiments:—"That it would be rarely advisable to risk a boat's crew for the purpose of using a charge of 40lbs., which must be placed in *actual contact* with the bottom of the ship it is intended to destroy. The uncertainty attending such an attempt must lead to failures. I consider that 100lbs. of gunpowder, or its equivalent in gun-cotton, is *the least charge* that should be used."

The use of such service charges would involve greater strength in the apparatus and longer poles.

Description of fitments.

Plate LXXXVII. is copied from the *Report of the Floating Obstruction Committee*, and the following description is extracted from it:—*a* shews the canvas covering, *b* the outrigger rigged in, *c* a stanchion, *d* the guide rod, *e* the fore and aft stays of iron, *f* the stays athwart ship, *g* the torpedo for 40lbs. of gunpowder or 10lbs. of gun-cotton, *g'* the torpedo for 100lbs. of gunpowder or 25lbs. of gun-cotton; the dotted lines shew the arrangement of boom recommended by the Committee on Floating Obstructions, the firm lines the form adapted for a charge of 40lbs. of powder only, *h* the foremost crutch, *h'* the pin to retain the outrigger in the crutch, *i* the after crutch, *k* the fore and aft awning pole, *l* the securing screw of the stanchion, *m* the securing screw of the cross piece, *n* the step for the stanchion, *o* the securing clamp for the stanchion, *p* the foot-board, *q* the cross piece, *r* the topping lift, *s* the in-haul, *t* the out-haul, *u* the conducting wire.

"Only one outrigger should be placed in position for act[ion] at a time, otherwise the first explosion might injure the oth[er] torpedo.

"It would be necessary to impart increased strength [to] these fittings to enable them to withstand the explosion [of] serviceable charges of 100lbs. and upwards of gunpowder. [In] an experiment of this description material injury was susta[ined] by the apparatus.

"The dotted line thus — - — - — - — represents the co[m]puted area of principal destruction of 100lbs. of gunpowd[er] at 'the depth of greatest effect.'"

Outrigger torpedoes are applicable for the attack of bo[oms], pontoon bridges, vessels at anchor or moving very slowly, [or] similar objects.

All steam launches and pinnaces, supplied to ships in H[er] Majesty's Navy, are now fitted with the side outrigger Torp[edo] gear above described. It does not seem to be, univers[ally] approved, in its present form, by naval officers. The follow[ing] seem to be the principal objections, which have been ur[ged] against the system by the German officers, who tried boats fi[tted] on this plan during the late war.

Objections to the system

1st. The boats are noisy, and the sparks from the funnel wo[uld] be very likely to betray them.

2nd. The fittings are complicated, clumsy and expensi[ve] costing about £40 per boat.

3rd. The charge, which is fired by electricity, the circuit be[ing] closed by hand, is likely to be exploded before touching the s[hip] during the excitement of an attack of this nature in the da[rk], especially as the boat must be brought into actual collision w[ith] the vessel attacked, bows on and at an very slow speed. If broug[ht] into contact at high speed, she could not be turned or backed o[ff] again in time to avoid being swamped by the sinking ship.

4th. The charge may be broken off from the pole and explod[e] while actually under the attacking boat, which would thus destr[oy] herself and leave the enemy unharmed.

5th. The boats are not fast enough for this service.

6th. Such boats would always run the chance of being dama[ged] by the explosion of their own charge, unless it was rigged to its full distance, or they might be swamped by the water [thrown] off the side of the ship attacked.

7th. Such boats would run a considerable chance of bei[ng] destroyed by an enemy.

A small charge on the end of a spar might, however, be used in repelling a guard boat in an attack upon a Torpedo boat.

Steel screens for steam launches and pinnaces.

The steam launches and pinnaces, supplied to Her Maje[sty's] ships, are now fitted with a steel screen, to protect the engin[e], boiler and crew during such attacks, the boat being steered [by] yoke lines from behind the screen.

Improved outrigger torpedo case.

An improvement has recently been introduced into the form of torpedo case, which is now fitted on to the end of the spar and lashed on through eye-bolts provided for the purpose, in a more satisfactory manner than that originally adopted. The cases now issued for service, are calculated to contain 100lbs. of powder.

German torpedo boats.

The following description of the German torpedo boats, gives an idea of the direction in which they (the Germans) consider it desirable toexperiment, in devising an efficient outrigger system.

The officers in charge of the defence of the North German ports, are strongly in favour of the extensive use of the offensive weapon, or torpedo, in addition to the defensive, or submarine mine. They consider, with reason, that a successful attack by torpedo boats on a blockading squadron, would prove a most powerful addition to the simply passive defence of even the most perfect system of submarine mines, and have accordingly turned their attention to the construction of a good form of torpedo boat.

At the commencement of the war they tried the system of outrigger torpedoes, adopted by the British Royal Navy. Their experience of these is, as already stated, highly unfavourable.

In consequence of the mishaps, which occurred in practice with the outrigger torpedo arrangements on the British principle, and the prevailing opinion among German naval officers as to the general unfitness of ship's boats, especially those propelled by steam, for torpedo service, efforts have been made to construct special boats for this purpose. Several of these are now in existence. They are in form an ordinary steam launch, about 50 feet long; a turret, about the middle of the vessel, contains the boiler and engines, with the funnel rising from its centre, while a smaller turret in front is arranged for a man to steer and command, small holes being left for him through which to see his way. The deck is made high in the centre, and curved over towards the gunwales. The whole deck, turrets and sides, to a short distance below the water line, are plated with musket-proof iron or steel. The torpedo is carried on an outrigger, projected from the boat's stem, at such a distance in advance that the boat herself may be safe from its explosion. It is attached by means of a tube in its rear, into which the outer extremity of thespar slips and is secured. A topping lift, working through the extremity of a short bowsprit, carries the spar, and by it the torpedo may be lowered to any depth required, or raised out of thewateraltogether. The magazine, to carry the torpedoes, is in the stern of the boat, and is completely cut off from the rest. A hatchway on the deck gives access to it. Another hatchway, further in advance, gives access to the front compartment, containing the engines, &c. Both hatchways are musket-proof. For electrical ignition the conducting wires are carried

from the torpedo through the bottom of the boat. The deck flush, and there is a low hand-rail round the stern to ass getting in and out, and to prevent spare spars, &c., falling board. The engines are arranged for surface condensati as to obtain the maximum of speed with a minimum of no

Speed of German Torpedo boats.

The speed attained by the boats now in existence is said about 10 knots. Some new ones are now being built to kerosine with the engines, from which it is hoped greater will be obtained, while at the same time a lower funnel m used. As little smoke as possible is shewn when under special precautions being taken to prevent it; with ker there will be no smoke at all. The entire boat, funnel is painted a light French grey, so as to render it as invisib possible. The boats are not intended to be submerged in way; this system having been found ineffective during American war.

Constitution of crew.

The crew of each consists of five men: one to steer and mand, two to work the engine, enclosed in the musket plating, and two to attend to the torpedoes. The heat the hatches closed, is said to be very great. These boats said to stand a moderately heavy sea very well, though might probably not be safe in a heavy gale. No difficulty been experienced in conveying the torpedo for any distance submerged position; and it is said to check the boats' when so carried, in a very slight degree. To put on a torpedo it is necessary for the men to come out on deck. operation of replacing a discharged torpedo may be perfo in a few minutes, either from the deck or from a small boat

Firing apparatus. Siemens' dynamo-electrical machine.

Siemens' dynamo-electrical machine is used, when elec ignition is employed, in combination with Abel's fuze.* approaching an enemy's vessel, a man turns the handle of machine continuously, and a self-acting circuit closing syste used, by means of which the electrical circuit is complete collision with the vessel, and the charge fired at the p moment.

Experiment to test efficiency.

No opportunity occurred for trying any of these boats ag an enemy's vessel. They were not built till nearly the e the war, and the French fleet lay a long way out at sea, near island of Heligoland, in such a position as to render the oper more than ordinarily difficult. An experiment was, howeve against the German iron-clad "König Wilhelm," to test efficiency. The vessel lay, with the remainder of the Germ squadron, well out at sea, near the mouth of the bay of Ja she was warned to expect an attack of this nature on a cer night. The torpedo boat came out with the ebb tide, and ra

* Since the war of 1870-71, the German officers have been experim with a platinum wire fuze, with a view to its universal adaptation for marine Mining and Torpedo Service.

GERMAN CIRCUIT CLOSERS,
FOR OUTRIGGER TORPEDOES.

Fig. 1.

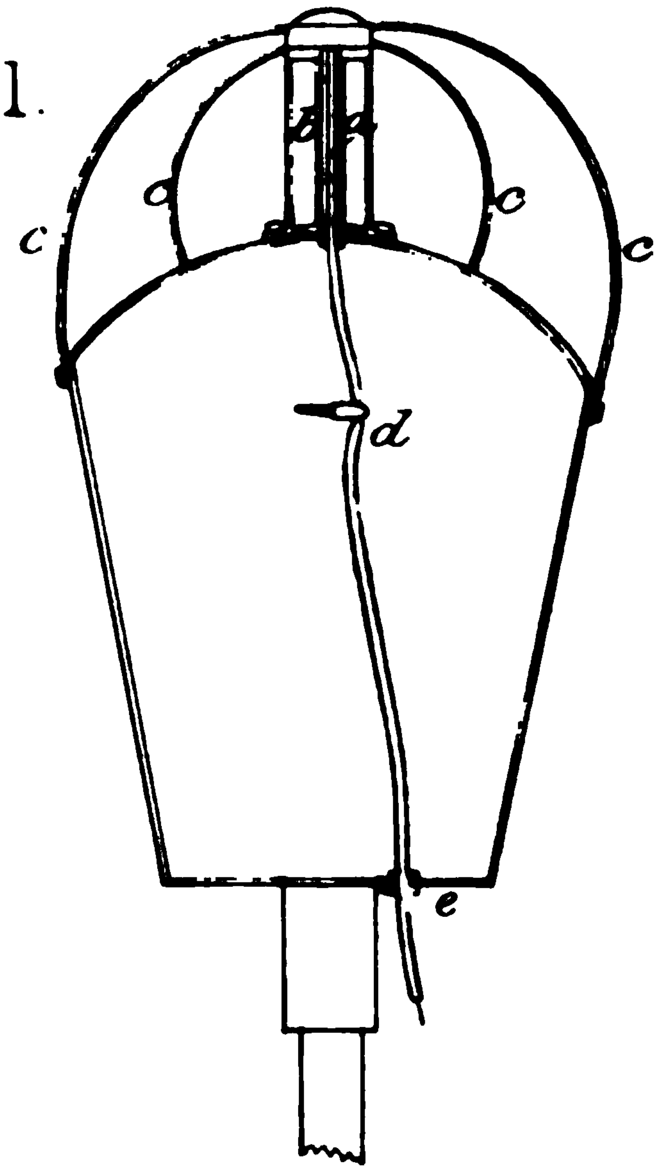
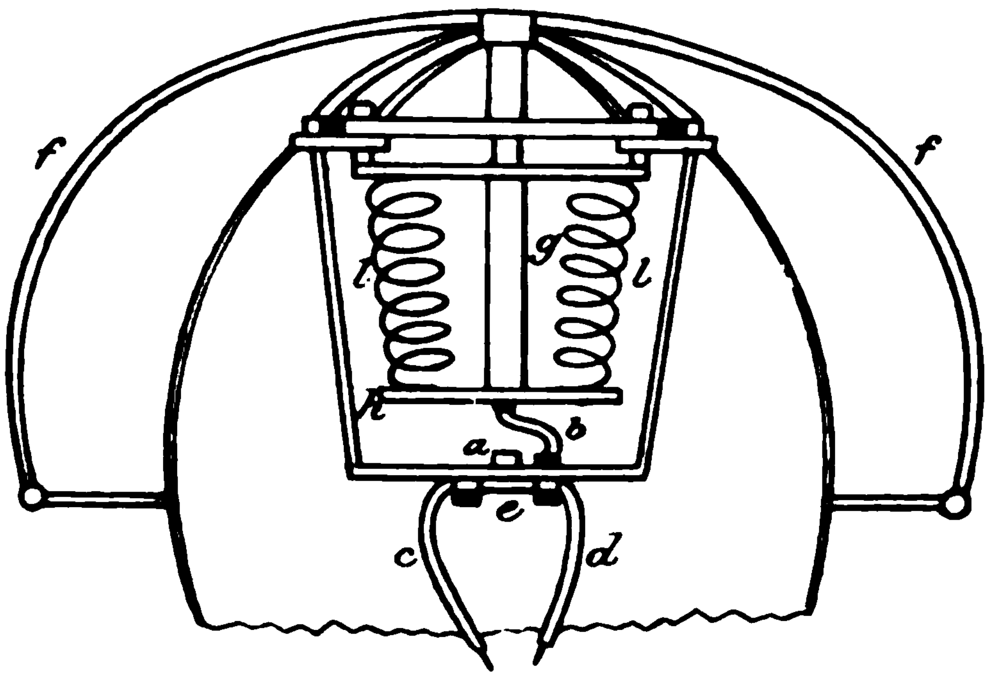


Fig. 2.



Lithographed at the S. M. E. Chatham. B. Butler, Corpl. R. E.

assing the guard boats, was alongside the "König Wilhelm" efore she could turn out her small-arm men to give her a volley, uch less get a gun out to fire on her. The result of the ex- eriment was considered highly satisfactory as far as the torpedo oat was concerned, both as regards speed, silence and invisibility. he came out of Wilhelm's-Hafen, a distance of about 10 miles, r this attack, and had to thread her way through the channel ft in the defensive mines and obstructions.

Circuit closers for outrigger torpedoes.

The Germans prefer the electrical form of ignition for their atrigger torpedoes to the mechanical, (though they at present nploy either system), and the self-acting electrical to that closed y hand.

Two different, self-acting, circuit-closing systems have been esigned. One of these consist of a glass tube, *a*, *Plate* LXXXVIII., *'ig.* 1, containing a metal earth-plate and hermetically sealed. his tube, held in a metal covering, *b*, just sufficiently strong to revent its being broken accidentally, is screwed by means of a ater-tight screw, provided with washers of leather, into the ead of the torpedo. A kind of cage, with arms, *c,c,c.*, *&c.*, ttached to its outer extremity and to the body of the torpedo self, ensures the fracture of the glass vessel by a blow in any irection, front or side.

The earth-plate, in the hermetically sealed glass vessel, *a*, is onnected with an insulated wire, to one terminal of an Abel's ıze, *d*, within the charge, while the other terminal of the fuze connected by an insulated wire, through a water-tight joint *e*, the rear of the torpedo, to the insulated wire passing through e bottom of the boat and so on to one terminal of the dynamo- lectrical machine. The other terminal of the dynamo-electrical achine being connected to earth, it only remains to turn the andle continuously, and as soon as the earth-plate within the lass vessel *a* is brought into contact with the water by the acture of this vessel, which would occur if driven against the de of the ship to be attacked, the electrical circuit would be osed through the fuze and the latter fired. This form of circuit oser is the idea of one of the men of the North German Torpedo orps; it has been tried with good results, and is much liked.

Another form of circuit closer for use with the outrigger rpedo, is shewn in *Plate* LXXXVIII., *Fig.* 2. The principle of tion in this form of apparatus consists in bringing a spring *b*, in ontact with an insulated conductor *d*, into connection with an ısulated conductor *c*, through the contact point *a*; the two con- uctors *c* and *d*, being attached to binding screws in connection ith an insulating disc *e* of ebonite. As long as *a* and *b* remain apart e circuit is broken; as soon as they are brought into contact the ircuit is closed. A pressure on the cage *f f*, by forcing down he arm *g*, effects the contact required; and this pressure would ccur if the apparatus were pushed against the side of an enemy's

ship. The parts are held asunder by means of two springs, i i, acting on a plate, *h*, in such a manner as to draw it up. The plate *h* must be insulated from the spring *b*. It is regulated to work on the application of a pressure of 60lbs. The whole apparatus complete is in the form of a small brass cylinder, so arranged as to be attached to the head of the torpedo by means of a series of nuts and screws round its circumference, made water-tight by leather washers, in the usual way. Supposing the conductor *c* to be in connection with the fuze, while *i* is connected to earth, and the connection with the dynamo-electric machine arranged as before, it may be easily understood that when the connection between *a* and *b* is made, consequent on the depression of the arm *g* transmitted from the cage *f*, the fuze will, as before, be fired.

This form of circuit closer is more complicated than that first described, and the springs *i i* are said to be liable to disarrangement and cannot always be relied on to remain uniform; it is not, therefore, so much approved as the former.

German, outrigger, torpedo cases.

The outrigger torpedo cases are made with a capacity to hold some 50lbs. and some 70lbs. of powder, the larger charge (70lbs.) being considered preferable. With dualine, or any of the more powerful explosives, the latter charge, fired in contact, would probably break the bottom of an iron-clad, however strongly constructed. We have no absolute knowledge on this point, however, no experiment having ever been made, under the conditions which would occur on actual service, to discover the minimum charge which would produce such a result. It is quite possible that less would do the work, but our only data are derived from the experiments with small charges against wooden targets, made by the Floating Obstruction Committee, which are manifestly inconclusive as regards iron structures.

The officer in charge of the German torpedo vessels, during the late war, gave orders that, in the event of an opportunity occurring, the boats should explode their charges in the vicinity of the screw or rudder of an enemy's ship; being certain so to disable her and uncertain of sinking her if attacked in any other part, or in other words, having no knowledge of the absolute effect which a charge of the size named would produce if such were exploded against a vessel constructed with a strong iron double bottom.

The torpedo boats described are large enough to work the 70lbs. charges with facility, and yet not so large as to be very conspicuous or to be difficult to manage. The German officers do not approve of small boats for torpedo service, as from them it is impossible to manage charges of sufficient size.

Several other forms of torpedo boat are about to be tried by the Germans, and some are now being built at other p

Whether they are an improvement on those described, must be ascertained practically.

The opinion of German naval officers seems to be adverse to the use of the fish torpedo, invented by Messrs. Lupin & Whitehead, because they suppose that from its small speed it is so liable to be acted on by currents, that the chance of hitting a vessel would be very small. They are equally adverse to Harvey's torpedo, because though excellent for day service, it could not, in their opinion, be used at night with any amount of certainty.

Opinion of German officers adverse to Whitehead's & Harvey's torpedoes.

Some improved torpedo boats, of very similar construction to those above described, though somewhat larger, have recently been built at Dantzic for the North German, Naval Service. The following description of them is extracted from a report by Lieut.-Col. Chesney, R.E., written in the autumn of 1871 :—

Improved German Torpedo boats.

"There are three of them at Herr Devrienne's yard, all far advanced towards completion, and one of them in the water, with her engines fitted and all but ready for trial. The three are all exactly upon the same lines, and what is said of the most advanced, will apply to each, except as regards the differences in their forwardness.

"The new steam torpedo boat is 68ft. in length by 10ft. in beam. As I saw her she was drawing about 7ft. of water, and had 18in. of her side above it; but with her water, fuel, and crew on board, she is calculated to go down within 13in. She will show, however, a good deal more above the water line than this, as her deck has a very considerable curve, rising about 9in. in the middle, in order to gain working room below.

"A light chain, run through standards of iron, goes round the deck for safety's sake. She is built of a light iron frame-work, plated over the sides with ¼-in. iron, and covered with ½-in. steel plate over the curved deck, so as to be completely musketry-proof above. The two hatchways, one forward, over a sort of cabin, where the crew would be gathered in the attack, and one aft for ventilation of the engines, are protected, not only by raised sides about a foot high, but by sliding steel shutters, which may be wholly or partly drawn.

"The funnel is about 2½ft. high in front, but cut away at the back. The general section lengthways is somewhat as shown in *Plate* LXXXIX., *Fig.* 1, the vessel drawing a good deal more water aft than forward, in order to gain room for her 3-ft. screw. She is divided across into five compartments, of very unequal size, by water-tight plating.

"Herr Devrienne seemed to pride himself more upon the engines than any other part of the work. Nominally they are of 20-horse power, made to consume petroleum, give out no smoke, are packed at every joint, work at low pressure, and are, in fact, intended to be as noiseless as possible. Everyone who knows the

ordinary steam launch, with its loud, highly taxed engine, will understand how very unfit it would be as an instrument of surprise.

"Steam launches were experimented largely with upon the Elbe during the late war. It was propably on practical observation of their extreme inapplicability for the purpose of using torpedoes offensively, that the orders were given to make the special vessels now reported on, which were begun before the late war was over.

"Herr Devrienne's engines are calculated to use their full supply of petroleum, (as allowed by the floatation), of 32cwt. in 24 hours. If acting without other vessels, therefore, the torpedo boats in question would be limited to that time. He anticipates that they will be found to do 10 knots an hour.*

"The steering apparatus is quite forward in the cabin, the tiller chains being ingeniously and simply conducted to the wheel, so as not to interfere in the least with the free action of the torpedo carrier itself, of which a description has yet to be given.

"Herr Devrienne had been experimenting with various models of this important part of the machine: one which was so far approved that it is to be tried on the vessel within a few days. It will be observed that, in the rough section of the vessel given in *Plate* LXXXIX., *Fig.* 1, there is shown a short bowsprit. This is mainly added to carry a pulley, through which to pass the tackle that would run the torpedo forward at the right moment.

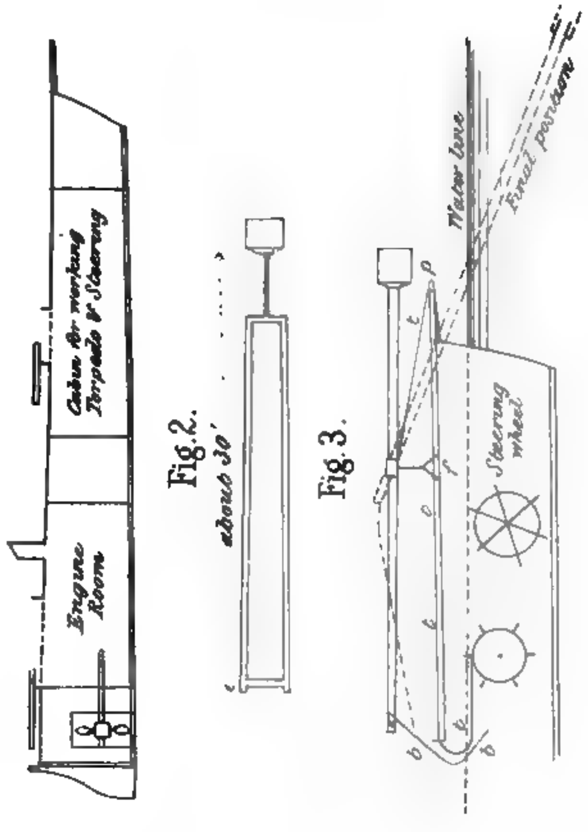
Mode of carrying Torpedo and rigging out.

"The carrier is shown in place in *Plate* LXXXIX., *Fig.* 2, and its action may be understood by reference to *Plate* LXXXIX., *Fig.* 3, it being supported on a light iron frame *f*, fixed on the deck over the middle of the cabin, until needed for use.

"The tackle *t*, *t*, *t*, running first through the pulley *p* on the bowsprit, from its attachment to the frame, is then carried along the deck to the hatchway of the cabin, and ends round a wheel which gives abundance of hauling power. When the carrier is run to a certain length forward, the torpedo's weight would tilt the front end downwards, and the torpedo itself naturally descend. A back guy *b*, *b* fixed upon the rear end of the carrier, and also carried into the cabin, is used to control this, and keep the torpedo above water until close to the object to be struck. Then the guy would be further slackened, and the torpedo allowed to decend to a point at which the guy has been previously marked and which would place the explosion, (to be made either by

* These boats have since been completed. In their first trials the petroleum fuel, as then applied, proved a failure. It was introduced for combustion with air only, and it was found that sufficient heat, to produce the necessary steam pressure, was not obtained, and the boats could not be propelled at a sufficiently high speed. Arrangements have since been proposed to introduce a steam jet, or jets, into the burning petrolium, with a view to the production of great heat. The result of this alteration is not known.

GERMAN TORPEDO BOAT.



Lithographed at the S. M. E. Chatham. *B. Butler. Corpl. R.E.*

electricity or concussion—a point not wholly decided upon), 18 feet horizontally from the boat, and 8 feet below the water line. Of course, these distances may be re-considered. The whole of this operation may be conducted without showing a man, indeed with the hatchway closed.

"The inventor's weak point, (or that of those who guide him), seems to be the difficulty of steering correctly with the wheel so shut in, and crowded between the bow and the torpedo tackle.

"Herr Devrienne states, that it was quite decided to use dualine as the explosive compound, and that thus loaded, the torpedo was found to weigh but 150lbs. in all, with an effective force of more than 500lbs. of powder. If this be so, the distance allowed from the bow of the boat seems to touch the proper limits of safety; but no doubt, careful experiments will be made on this point.

"In the important point of seaworthiness the constructor does not conceal his opinion, that his vessels are not really fit for a sea-way. They are intended, he states, for nearly smooth water. With that condition, and used with a perfectly trained crew, they would be formidable indeed. A single cannon shot would send one to the bottom, no doubt, but their extraordinary lowness would render them very difficult to hit: if seen or heard, when so near an enemy that she could no longer depress her big guns, they are purposely made proof against musketry, as before stated."

Mode of attack suggested by Commander Stewart, R.N.

The following mode of attack by an offensive torpedo, has been suggested by Commander Stuart, R.N., late Instructor in Electricity on board H.M.S. "Excellent." He proposes to carry a charge over the side of a small boat, attached to a line about 12 feet long, and fitted with the usual arrangements for firing by electricity. To pull alongside the vessel to be attacked, in a boat painted an invisible colour and with muffled oars, choosing the weather side as that to be approached. To attach the line, in connection with the charge, to the chain cable or any ring or bolt in the side of the ship, back out about 50 yards and fire the charge. In the case of a wooden ship it might be secured by a gimblet or staple, if no ring could be found in a suitable position. He is of opinion that this method would ensure the charge being placed and exploded in the right position with certainty, there would be greater chance of getting clear of the vessel after the explosion and less chance of being observed. He also suggests this method of operation to scuttle a ship on fire, for which it seems very applicable.

Harvey's sea Torpedo.

Harvey's sea torpedo also belongs to the first class of weapon, being manœuvred from a ship in motion. It is a joint invention of Captain John Harvey, and Commander Frederick Harvey, R.N., and consists of a case, *a*, of No. 18, B.W.G. sheet copper,

of the form shewn in *Plate* XC. This case may be made of any size; the dimensions, as shewn in the figure, are those calculated to contain a charge of 76lbs. of gun-cotton, or an equal bulk of other explosive. This charge would probably be sufficient to sink any vessel, if fired in contact with her hull, and is of convenient size to work with facility from a ship's deck. The form adopted is similar to the machine called an "otter," used by poachers for fishing purposes, and its mode of propulsion through the water is identical therewith. Outside the sheet copper, which forms the internal water-tight portion of the apparatus, is a thick wooden casing strengthened with iron plates, to preserve the former from injury. To the bottom of this wooden casing is attached a keel of iron, *b*, with a leaden covering on the lower side, to keep the apparatus upright while floating in the water. The weight of iron used is regulated by the speed of the vessel from which the torpedo is to be manœuvred, and it should be sufficiently great to sink the whole apparatus when complete with charge, &c. This capacity to be submerged at will is essential to the proper manœuvring of the apparatus, and, when the towing line is cut away, its effect is to sink the whole torpedo to the bottom and thus prevent chance of injury to a friendly vessel. Lines are arranged as shewn at *c*, to enable the torpedo to be towed at an angel, diverging about 45°, from the direction of the course of the vessel from which it is worked. The towing line is composed of several strands of galvanized steel wires, over a hemp core, forming a $1\frac{1}{4}$-inch wire rope. The towing line passes through a ring in connection with the guiding ropes *c*, thence through another ring, *d*, on the stern of the apparatus, and is connected with a buoy, arranged to prevent the torpedo sinking too deeply for subsequent work during any temporary slackening of the towing line. A knot on the towing line prevents the buoy being drawn too closely up to the torpedo, but being beyond the ring *d*, directly the towing line is cut at any point, the latter slips through and the torpedo itself is disengaged and sinks.

Nature of explosive used.

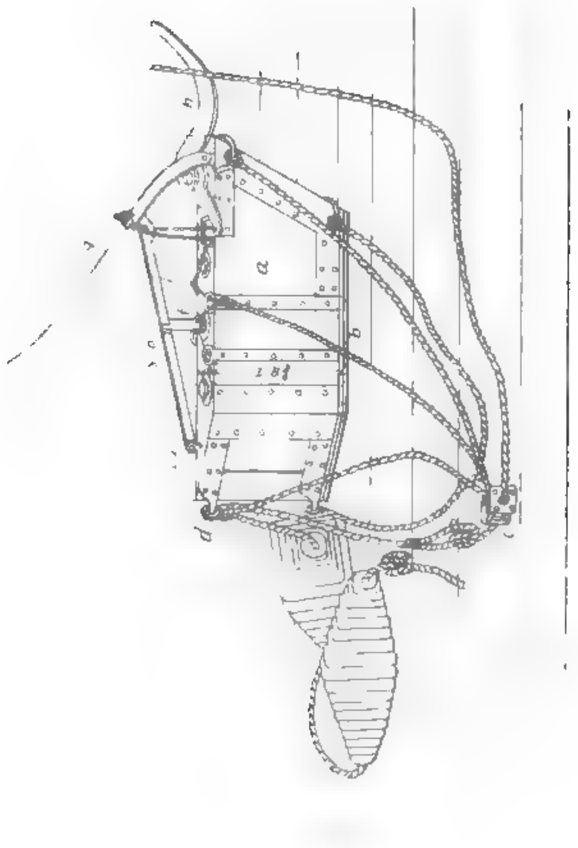
The charge of gun-cotton, or other explosive, is contained in two compartments within the sheet copper case, which is divided in the middle. A loading hole, $1\frac{1}{2}$ inches in diameter, to be closed by a water-tight screw plug, is provided for each compartment.

Mode of firing.

The charge is arranged to be fired by means of a metal bolt *f* in connection with a sulphuric acid fuze. When the bolt is forced down it breaks a glass vessel containing sulphuric acid which, falling on a chemical mixture produces heat and fires the priming of the fuze, which in its turn ignites the charge. The priming charge is contained in a vertical copper cylinder, placed in the centre of the torpedo and only divided from the two sections of the charge by the thin metal of which the cylinder is composed. The fuze piece, with firing bolt, &c., complete, is carried separate

PLATE XC.

HARVEY'S SEA TORPEDO.



Lithographed at the S.M.E., Chatham. B Butler, Corpl R.E.

›m the charge, and only screwed into it just before the torpedo launched overboard for the attack of a vessel. The firing bolt provided with a safety key, passing through a hole in the ·mer, and till it is removed the bolt cannot be pressed down and e charge cannot be fired: this key is drawn out by means of ine attached to it and veered out from the ship simultaneously th the tow line. The firing bolt may be arranged to explode e fuze on any given pressure being applied, for this purpose pressure of about 60lbs. has been found to be convenient. The essure required to withdraw the safety key should be arranged about 30lbs. Pivotted on the bow of the torpedo are two levers and *h*, one *g* passing vertically over it towards the rear, the her *h* on the side of the apparatus which is most likely to come contact with the vessel to be attacked, always on the opposite de to the directing lines *c*. The lever *g* is arranged over the ead of the firing bolt: on coming in contact with the bilge of a essel, it would be pressed down, carrying with it the lever *i* and e firing bolt, which would break the glass capsule containing e sulphuric acid, and thus fire the fuze and consequently explode e charge. The lever *h* performs the same office when acted on side pressure against a vessel; when pushed inwards towards e torpedo, it draws in a lanyard in connection with the lever *i* ıd pulls this latter down, acting on the firing bolt with the me result as before.

Different forms of torpedo required for each side of ship.

Different forms of torpedo are employed for each side of the essel, the lever *h* being always so arranged as to be on that side f the apparatus which, when floating in the water, is away from e ship from which it is manœuvred, the tow lines being on the de nearest to the vessel.

Mode of manœuvring

In order to manœuvre torpedoes of this nature, the ship should e provided with a couple of drums, with brakes attached, on ither quarter. One of these drums carries the tow line, and the ther the safety key line, with are veered out uniformly together; he drums should be of such dimensions as to hold a length of 240 athoms of each. To attack a vessel, the proper torpedo is launched verboard by its towing line and gradually veered out to any distance equired, usually about 150 yards, the vessel being kept in motion uring the whole process. The brake is then put on, which has he effect of bringing the torpedo to the surface and carrying it long in a line parallel to the ship's course, and diverging from er quarter at an angle of 45° and at any distance, from 150 ards upwards, that may be required. A reserve of about 150 ards of line is kept on the drum for future use. The torpedo s visible, from the deck of the vessel using it, during the whole f this operation, and its approach towards the vessel to be attacked may be readily watched. As it approaches its object, the afety key is withdrawn by means of the line provided for the urpose, the brake is relaxed and, the pressure on the towing line

being thus removed, the torpedo sinks for a moment, the b... is again applied just at the time when it is supposed the torp... is under the vessel to be attacked, it rises in consequence of ... pressure thus applied to the towing line, comes in contact ... the bilge, one or both levers are forced down, and act on ... firing bolt, and the charge is fired.

Electrical mode of ignition.

Commander Harvey has applied Capt. McEvoy's circuit ... for firing his torpedo by electricity; he seems, however, to pre... mechanical ignition on contact, in consequence of the dange... fracture or injury to be apprehended in veering out the insu... conducting wire, which must be placed in the centre of the to... line and consequently be subjected to a considerable strain ... is of opinion, moreover, that electrical ignition would not ... any circumstances, be so certain in its action as mechanical ...

Most useful application.

Experiments with this form of torpedo have been carri... by the Government at Portsmouth and Plymouth, and it ... manœuvred with great success. To render it thoroughly effi... however, in rough water and in the open sea, much skill and p... tice is necessary. This apparatus is adapted for the attack ... vessels at anchor or in motion, but it is in the latter service, ... in a rough sea or smooth water, that its peculiar advantage... most apparent. It has been approved by our naval auth... and is now issued to some of Her Majesty's ships.

High speed essential in manœuvring Harvey's sea torpedo.

In order to manœuvre this torpedo to advantage, Comma... Harvey prefers a high speed. He is of opinion that it can... well at a less speed than six knots an hour. This fact ... important bearing in limiting its use, especially at night ... narrow waters.

Harvey's torpedoes, with the necessary brakes, &c., are ... supplied to all sea going iron-clads in Her Majesty's ser... They are of two sizes; the larger to contain 76lbs. of rifle gr... powder, or its equivalent in bulk of any other explosive, ... fitted to be used from the vessel herself; the smaller to con... 27lbs. of rifle grained powder, or its equivalent, to be manœ... from a steam launch or pinnace, by which it can, however, ... be towed at a speed of about $4\frac{1}{2}$ knots in very smooth wat... rate considerably lower than that recommended by the inve... as already stated. If a steam launch could be construct... tow one of Harvey's torpedoes at a high speed, there is no d... that it would prove a very effective weapon for purposes of at... During such an operation the boat's speed need not be red... at the moment of contact, as mentioned in the case of an at... by the outrigger torpedo.

Lupin and Whitehead's fish torpedo.

As regards the second class, or projectile torpedoes, one of ... most promising is that invented by Messrs. Lupin and Whitehe... A considerable amount of secrecy has been observed with refere... to this machine, but the following, as far as can be ascertain... a description of it.

It is fusiform in shape, and is provided with projections re- *Construction*
mbling fins and some kind of rudder, by means of which it
ıy be set to run in any particular direction and at the same
ne the depth, at which it is to move below the surface of the
ıter, is regulated. The fins also serve to guide it in passing out
the tube, through which it is discharged into the sea. Motive
wer is given by means of compressed air, which is made to turn
'our-bladed screw propeller. The speed attained is about eight
d a half knots an hour. Direction is given to the torpedo by
ɔans of an iron tube, fitted into a vessel in such a position as
discharge it at a considerable depth below the surface of the
ıter. The tube constructed in H.M.S. "Oberon," for experi-
ɔnts tried with this torpedo last autumn at Sheerness, was
t. in diameter, 28ft. long, and directed horizontally through
ɔ bow: its outer extremity was covered by a metal cap. The
be was divided into two portions, and was provided with two
rtical sluices to keep the water out.

Mode of projecting torpedo. The rear sluice having been opened, the torpedo is passed into
ɔ tube on rollers:—the rear sluice is then closed, the front one
ened, and, the cap covering the outer extremity of the tube
ving been removed, the torpedo is expelled from the ship by
ɔans of a piston;—during this process, the fins serve to prevent
y turning motion, by bearing upon four rails, the upper and
der ones being provided with friction rollers placed within the
be to serve as guides for this purpose. As it passes out, a
pper catches against a stud in the tube and puts in action the
ɔpelling power. Direction is given, or, in other words, aim is
ken, by moving the ship herself as required.

Position of charge. The charge, which may be of gunpowder, gun-cotton or any
ıer explosive, is carried in a chamber in the head of the torpedo,
d ignition is affected by means of a percussion fuze.

Experiments to test the use of torpedo. Numerous experiments were tried during the autumn of 1870
th torpedoes of this nature, without an explosive charge, to
ɔertain their capacity to move at given depths below, and in a
ɔen direction through, the water, and these having proved fairly
ccessful, an experiment with a loaded torpedo was decided on
d carried out at Sheerness on the 8th of October, 1870. The
arge used on this occasion was 67lbs. of gun-cotton:—the
rpedo was discharged, from a distance of about 150 yards, at an
l hulk, called the "Aigle," moored at the mouth of the Medway;
ɔ hulk was struck and sank immediately. The explosion threw
a column of spray and smoke mixed with coal dust to a height
about 70ft. The spray was perfectly distinct from the
ıoke and coal dust and proceeded from the water disturbed
tside the vessel's hull:—the smoke and coal dust being probably
e to the explosion acting inwards, through the vessel's side, and
ɔ column of gas driven through the interior of the ship. The
o sections of the column, viz.:—the white spray and the black

smoke and coal dust, were entirely distinct from each other
not mingled in any way.

Effects of explosion.

The damage done by this explosion consisted of a clear
the side struck, (the starboard side), 26ft. long and
depth, and extending down to the keel; — about 4ft.
planking above this hole was broken, and the copper more
torn off for a length of about 40ft. Inside the hulk,
main deck, up to the mizen hatchway, was carried away
remainder much torn and injured. On the upper deck the
round the hole, left by the removal of the mizen mast,
placed and forced upwards for a distance of about 1
planking on the port side of the vessel was blown outwar
a length of 16ft. and to a depth of 2ft., while it was shak
a further distance, and the copper more or less stripped
area extending considerably beyond the space mentioned
considering the extent of damage done, it must be
mind that the "Aigle" was an old wooden vessel, probably
what rotten, and it is scarcely likely that this amount of
would have occurred had the same torpedo been exploded
the side of a ship so strongly built as a modern iron-clad
is, however, a question for the consideration of naval arc

Fish torpedo fired from boat.

A small torpedo of the same class, 14ft. long,
diameter, and carrying a charge of 18lbs. of glyoxalin
subsequently fired from an apparatus suspended beneath
which was placed at a distance of about 150 yards fr
"Aigle," and directed at some netting arranged to protect the
against an attack of this nature. The torpedo was fired
tact with the netting, but did no apparent injury to the
The netting was hung about 16ft. clear of the vessel's side.

Conflicting influence of currents, &c.

This torpedo must necessarily start with a low velocity
at its best, as at present arranged, does not attain a speed
than eight miles an hour, which would render it somewha
to disturbance from the effects of currents. Its performa
the whole, during the series of experiments carried on
has, however, produced a favorable report on the part
Committee charged with the investigation of its efficienc
considerable sum has been, in consequence, paid to the inv
for the right to use this apparatus, and a special vessel
under construction at Woolwich for use therewith. Ac
to the inventors, it may be employed with considerable
at a distance of 800 yards in the open sea.

Torpedoes propelled by rocket composition

Mr. Lancaster, the gun maker, made a proposition
Government some years ago, to propel a torpedo throu
water, by means of rocket composition, carried in the body
apparatus; his ideas, however, were not approved, and
quently, were never worked out. The idea is not, by any
novel: it has been proposed from time to time by variou
tors, notably by the French General Paixhan, by whom

tried without success. Up to the present time, the experiments tried in this country do no auger favourably as regards its practical application. More recently, Mr. Quick, Engineer of the Royal Navy, has brought forward a similar proposition. His idea is, that a torpedo thus propelled, could be discharged through a tube, fixed in the side of a vessel at about 10ft. below the water line, and afford a ready means of making a breach in the bottom of a ship below her armour. An experiment has been tried by the R.E. Committee to test its value.

Experiment with Quick's torpedo.

This experiment was carried out at Shoeburyness on the 20th June, 1872. The following is a record of the result:—

"The torpedo used on this occasion consisted of four rocket tubes, each containing 10lbs. of rocket composition, bound together, enclosed in a copper case.

"In the head of the torpedo was a chamber, to contain a powerful explosive, ignited by a percussion fuze at its "point."

"The weight of the torpedo was 300lbs. Displacement 150lbs.

"The torpedo was placed below the water in a 10-inch smooth bore gun, which was laid, at Mr. Quick's request, at an angle of elevation of 5°. The axis at the bore of the muzzle being 5ft. from the bottom, and at high water 3ft. 6in. from the surface of the water. The muzzle of the gun was stopped with glass, and the vent, through which the firing wires were led, was also made water-tight. The torpedo was successfully ignited, and when it had issued some 3 or 4ft. from the muzzle of the gun—that is when the tail of it was clear—it suddenly rose out of the water, separating into several parts, viz.: four rocket tubes and the case, two of the rocket tubes attaining a height of as much as 50 or 60ft. On picking up the pieces, one of the rocket tubes was found to have burst. Mr. Quick, (see letter enclosed),* expressed himself quite satisfied with the Committee's arrangements, and he seemed also satisfied that the failure of this, his first important experiment, can be rectified by the employment of better rocket composition, &c. With this assumption the Committee are not inclined to agree.

"The Committee had considerable doubts as to recommending the trial that has taken place, but they thought as the question was one that had occurred more than once to the minds of military and naval men, it would be well to elicit some information on the subject.

"The result of the experiment confirmed the Committee's opinion, that it is scarcely possible to impel a torpedo in a direct line by means of the motive force developed by rocket composition, unless it be provided with very efficient steering apparatus, and that the unavoidable variations in the uniformity and rate of burning of

* This letter is one written by Mr. Quick to the Royal Engineer Committee. It has not been considered necessary to print it here.

rocket composition, must render the elaboration of a steering apparatus which is susceptible of self-adjustment to meet these variations, a very difficult problem, on account of the great influence which very slight variations of the motive force must exert, in promoting the deflection of a rocket from its course when fired under water.

"These very serious, if not unsurmountable, obstacles to success would exist, even if the torpedo were propelled by one single rocket, but they are greatly increased by the employment of several distinct rockets as the propelling agent in one torpedo.

"Even if the rocket composition in the several tubes be ignited simultaneously, a slight want of uniformity and density in the composition will cause unequal burning, and consequently deflection from the desired path. Each rocket will endeavour to rotate on its own axis, but being prevented from so doing, a centrifugal motion, perpendicular to the axis of the rocket, will be thereby imparted, which must be productive of indefinite error.

"The Committee consider, that the result of the experiment with Mr. Quick's torpedo, did not afford the slightest indication that any prospect of success would attend his attempts to apply rockets as a motive force for torpedoes, and they see no prospect of any useful result attending a further prosecution of experiments in this direction."

Ballard's idea for steering a torpedo.

Some short time ago, Colonel Ballard, R.E., suggested the idea of steering a torpedo by electricity. He proposed to employ a relay battery in the torpedo itself, by which a rudder could be worked, the relay being set in action by means of a primary current passing through two insulated wires, to be reeled out from the torpedo itself as it advanced through the water. The motive power proposed for the torpedo, might be compressed air, or any other agent by which the desired result of progression could be attained. This system was tried with fair success by the officers of H.M.S. "Excellent," the object aimed at, which was generally a boat in motion, having been hit, or nearly so, at distances of from 150 to 500 yards. The steering apparatus, during the trial, was fitted to a steam launch. Certain objections were, however, raised against the arrangement, the chief of which were, that it would be very difficult to steer the torpedo in this manner at night, that the electro-magnets, in connection with the relay, did not act with certainty, and that it was impossible to get the helm amid-ships, with any certainty, after it had been put over either one way or the other. The first objection is unavoidable:— it is manifestly necessary to success that a torpedo steered in this way must be seen by the man steering it; on the other hand, a capable of being steered, even over a short distance at night, it possesses a manifest advantage over one that could not be steered at all. The second and third objections are not insuperable:— a relay is not a very complicated electrical arrangement, and with

a little adjustment, might no doubt be made to work satisfactorily, and in the report on the result of the experiments tried, it is mentioned that the helm might be made to fall automatically amid-ships, on the cessation of the steering current, by a re-adjustment by the mechanical arrangements. The idea of steering a ship by electricity, from a distant point, is not new; it was proposed by Captain W. H. Noble, Royal Artillery, in a memorandum to the Ordnance Select Committee, dated 1st March, 1862, as a means for guiding a fire ship. This application of electricity has also been suggested by others.

Electrical steering proposed by Captain W. H. Noble, R.A.

Colonel Von Scheliha, who is well known as an authority on submarine warfare, has devised a torpedo, capable of being steered on very similar principles to those proposed by Colonel Ballard. This apparatus has been tried at St. Petersburg, with considerable success.

Von Scheliha's steering torpedo.

Major Beaumont, M.P., R.E., who was present during one of these experiments, was so favourably impressed with the idea, that he has himself suggested a system of electrical steering for trial. It has also been favourably reported on by the British Military attaché, at St. Petersburgh. There can be no doubt that experiments, to test the value of this system, are most necessary.

Electrical steering proposed by Major Beaumont, M.P., R.E.

Mr. Quick, Engineer in Her Majesty's Navy, has suggested the idea of steering an outrigger torpedo boat, electrically, by means of lines led into another boat towing 50 yards' astern. The value of this idea could best be judged by naval authorities. If, however, a boat must be sacrificed in such an operation, it would probably be easier for the crew to remain in her till within 50 yards of the vessel to be attacked, and then get out into another boat, letting the first move on by herself, ("rip" as it is termed in naval language), than to burden themselves with the complications of electrical steering gear.

Electrical steering arrangements proposed by Mr. Quick.

Projectile torpedoes might be used against ships at anchor, or perhaps moving slowly, also for the destruction of obstructions extending to any considerable depth below the surface of the water. They do not seem applicable to the attack of pontoon bridges or booms, as the chance of striking such objects would be comparatively small, unless the power of regulating the depth at which they would move below the surface, is capable of being very nicely adjusted.

Use of projectile torpedoes.

Among the various devices suggested at different times for the third class or drifting torpedoes, the most promising seem to be those designed by Captain McEvoy, of the late confederate torpedo service, now the London Ordnance Works, Bear Lane, Southwark, and by Lieut. J. F. Lewis, R.E.

Drifting torpedoes.

The following description of McEvoy's, self-acting, drifting torpedo, is extracted from the *Report of the Floating Obstruction Committee*, published in 1868.

McEvoy's drifting torpedo.

Construction

"The torpedo case is to be suspended from a float, and permitted to drift down upon an enemy's floating bridge in a river, or against a vessel at anchor, but is specially suitable for the former purpose.

"On the top of the exterior, protected by iron bars, is a sensitive percussion fuze, with a hammer retained at full cock by a lever, which is acted upon by the threads of a screw. To this screw is attached a many-bladed screw propeller of sheet tin, balanced by a fan or rudder blade on the opposite extremity, the whole pivoting round the percussion fuze, and occupying little space.

Mode of action.

"So long as the torpedo continues to drift, the apparatus on its top will be unaffected by the current, but as soon as the motion of the torpedo is interrupted, the current running past will act on the fan or rudder blade and turn the screw propeller to the current, when a given number of turns will liberate the hammer and cause explosion."

Plate XCI. shows the general design of the apparatus: *a* is the sensitive fuze, *b* the hammer, retained at full cock by pressure against the catch *k*, which works in the threads of the screw; *c* is the fan to turn the screw propeller, pivotted round the fuze *a*, to the current when the torpedo ceases to drift; *d* is the screw propeller of sheet tin, to be revolved by the current when the torpedo fouls anything and ceases to drift; this action would disengage the catch *k* and allow the hammer to fall and ignite the sensitive fuze *a*; *e*, *e* are circular guards to protect the igniting apparatus, *f*, *f* iron slings, *g* the suspension rod, and *h* the surface buoy. This figure is copied from the *Report of the Floating Obstruction Committee*.

Lewis' drifting torpedo.

The following description of Lieutenant Lewis' self-acting drifting torpedo, is extracted from the *Report of the Floating Obstruction Committee*.

"This is a contrivance for projecting drifting torpedoes, under booms or other floating obstructions employed for the defence of ships at anchor.

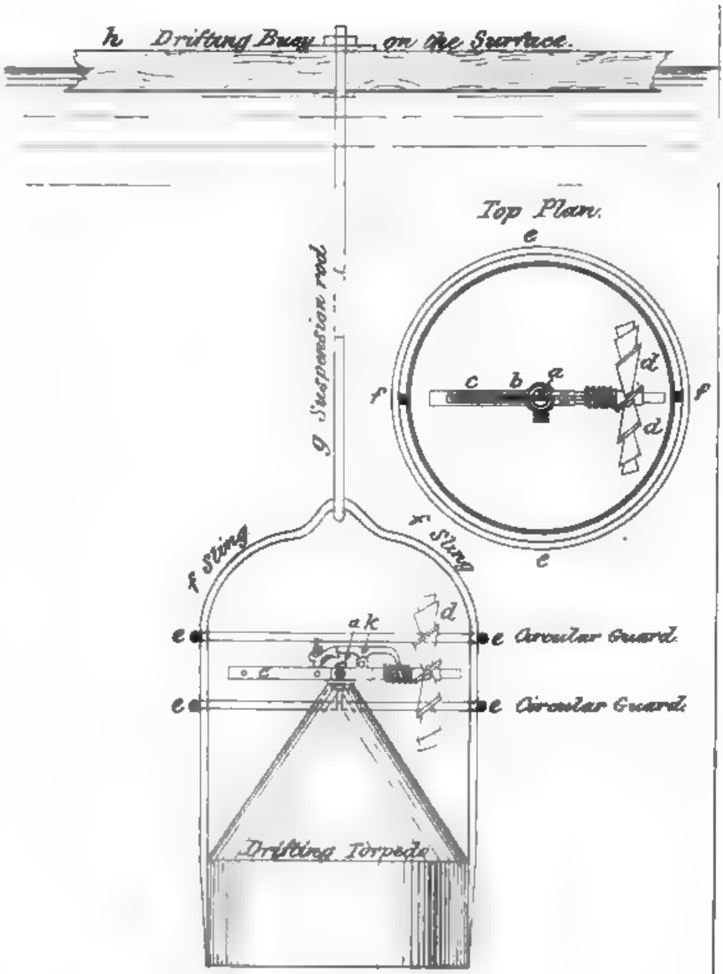
Construction

"The torpedo consists of a cubical box, capable of containing 55lbs. of powder, and furnished with five detonating fuzes in one of its sides.

"This torpedo is attached to one side of a beam, and within six inches of one extremity—the beam being 20ft. long and 7in. square. To the opposite side of the same end of the beam a 60lb. iron weight, resting in a shoe, is attached by a long iron rod which reaches to the other extremity of the beam, and is there connected to a bell-crank lever and spring, a pressure on which detaches the weight. A chain 18ft. long connects the weight loosely with the upper end of the beam, and another chain 9ft. 6in. long connects it with a point more than two feet below the centre of the beam. The whole arrangement floats nearly vertically, with the top of the beam just above the surface of the water.

PLATE XCI.

McEVOY'S DRIFTING TORPEDO.

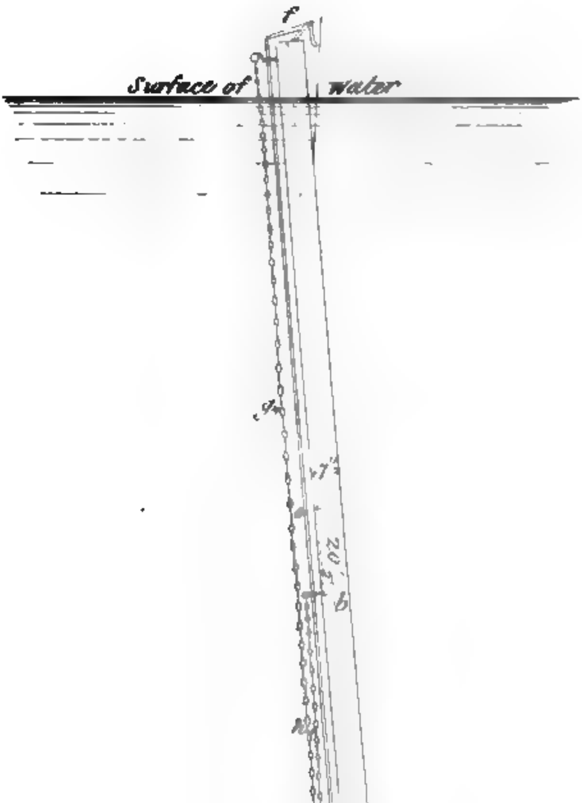


Lithographed at the S. M. E. Chatham.

B. Butler. Corpl. R. E.

PLATE XCII.

LEWIS' DRIFTING TORPEDO.



ached at the S M.E Chatham. B. Butler, Corpl R.E.

"When the apparatus drifts against a boom or other obstruction, the spring or lever at the upper extremity is pressed down, thus raising the long iron rod and releasing the weight, which falling, becomes suspended by the two chains, throwing the beam into an inclined position. The weight of this mass of iron and the chain suspending it, are suddenly brought to bear on the top of the beam, dragging it under water and clear of the floating obstructions, at the same time the lower end, released from the weight, rises, and the whole apparatus is carried forward by the current against the side of the vessel, on striking which the torpedo explodes." *Mode of action.*

Plate XCII. shows the general form of the apparatus, *a* is the box containing the charge, *b* the beam to which it is attached, *c* the 60lb. weight, resting on a shoe, *d*; *e* is the iron rod connecting it to the bell-crank lever and spring, *f*; *g*, and *h* are the two chains connecting the weight to the beam.

Use of drifting torpedoes.

Machines of this nature might be used for the attack of pontoon bridges, booms and obstructions generally; those exhibiting a broad face being the most likely to be injured by them. Being dependent on the force and direction of currents, it would be necessary to study both carefully before proceeding to undertake any operation involving their use; and, in a tide-way, it should be borne in mind that, if carried in one direction, towards an enemy for example, by the flood tide, they would, unless expended, return towards their friends with the ebb. The two forms described are not very expensive or difficult of construction, if to be used therefore, it would seem desirable to employ very large numbers as, from their nature, it is probable that a large proportion would prove ineffective. The consternation and confusion, described in Commander Barnes' book on submarine warfare, as as having occurred among the British ship's in the Delaware, on the 7th January, 1778, when a number of kegs, filled with powder and arranged to be fired on contact by a simple gun-lock, were drifted down to attack them, shows how much may be done with extremely rough means. An attack by drifting torpedoes in large numbers is, therefore, quite applicable to certain cases, and may be successfully employed.

Defence of ships from offensive torpedoes.

The best method for the defence of ships against an attack by offensive torpedoes, is a subject which has still to be investigated experimentally. Such attacks would almost always be made at night. Nets and spars would doubtless be a protection, but these are only applicable to close harbours, or where there would be no likelihood of a sudden move being required. In more open waters, or where the above appliances would not be admissible, a vigilant look-out, with plenty of boats rowing guard would be necessary. Such boats should be supplied with signalling apparatus, as well as with the means of attacking a torpedo boat. The steam up and cables ready to be slipped; the men

sleeping at their quarters, and the ready use of the ships armament or of mitrailleuses, would appear to be the best means of defence available, in addition to the guard boats above mentioned.

FINIS.

List of Prices of Special Articles, required for Submarine Mining Service.

NOTE.—*The prices quoted for iron work, were those paid for supplies chiefly obtained in* 1871. *In consequence of the great increase in the cost of iron since that period, it is probable, that at the present moment* (1873) 50 *per cent., at least, would have to be added to the prices named in the following list.*

Article			Unit	£	s.	d.
Acid	Muriatic		lb.	0	0	2
	Sulphuric		,,	0	0	2
Attachment chains	3-legged		each	0	2	4
	for ground mines	500lbs.	each	0	8	0
		250lbs.	,,	0	8	0
Batteries	Daniell, with terminals		box of 10 cells	1	1	0
	Leclanché, No. 3 size, cells		each	0	2	3
	Walker, with bridge		box of 10 cells	4	2	6
Beeswax			lb.	0	1	9½
Belts, leather, 4-inch, for winding apparatus			ft.	0	2	10
Brass, sheet			lb.	0	0	10½
Bunting	Black		yd.	0	0	8
	White		,,	0	0	8
Buoys, iron, galvanized, 2-feet			each	0	16	0
Cables, electric, submarine	Single armoured	India-rubber Co.	knot	74	0	0
		Hooper	,,	74	0	0
		Henley	,,	83	0	0
		Circuit closer	,,	127	0	0
	Multiple	7-core	,,	357	0	0
		4-core armd.	,,	202	0	0
		4-core unarmd.	,,	137	10	0
Cable, electric, telegraphic, single, unarmoured, per knot				33	10	0
Carbon	Plates for Walker's batteries		each	0	1	0
	,, Leclanché ,,		,,	0	0	6

Cases, submarine mine	500lbs. buoyant ...	each	9	17	6
	500lbs. ground ...	„	7	3	6
	250lbs.	„	6	19	0
	100lbs. electro-contact, complete, with jacket, circuit closer, chains, &c. ...	„	13	5	4
Chain, iron	$\frac{3}{8}$-inch	fathom	0	2	6
	$\frac{7}{16}$ „	„	0	2	9
Circuit closers, complete, with jacket, internal mechanism, &c.		each	11	15	9
Cloth, emery		quire	0	1	2½
Coils, resistance	10,000-ohms, with bridge,	each	20	0	0
	100-ohms, firing	„	4	10	0
	1000-ohms, testing	„	0	5	0
Copper	Sheet	cwt.	4	0	0
	Sulphate of	lbs.	0	0	4½
Cordage, (see vocabulary) ...		...			
Cotton waste, white		cwt.	1	16	6
Crabs	hand, large, to lift 3 tons	each	7	12	0
	hand, small, to lift 1½ tons	„	5	8	0
	steam	„	70	0	0
Davits, iron tube		„	10	0	0
Disconnectors		„	0	5	6
Dishes, porcelain, 19″ × 15″ × 2½″ ...		„	0	10	0
Drums	iron, single cable, ½-knot	„	14	9	6
	iron, multiple „ „	„	29	4	6
	wooden, 1-knot ...	„	5	2	6
Dynamo electric apparatus, Siemens'		„	20	10	0
Engines, 3-horse power, on wheels...		„	135	0	0
Extractors for mouth pieces ...		„	0	5	0
Exploders, Wheatstone's ...		„	17	0	0
Flags, Army signalling, set of 3 ...		„	0	5	6
Funnels	ebonite, 5-inch ...	„	0	2	6
	glass, 1-pint ...	„	0	0	2
Fuzes	electric, Abel (old service fuze)	No. 1	1	16	7
	„ „ submarine ...	No. 2	2	17	7
	„ platinum wire ...	No. 3	2	6	1
	detonator, electric, Abel (similar to No. 1)... ...	No. 5	2	6	0
	detonator, electric, Abel, submarine	No. 6	3	11	6
	„ „ platinum wire	No. 7	3	10	10
	„ for Bickford ...	No. 8	2	4	6
Fuze pieces, ebonite, with zinc guard		each	0	7	0
Galvanometers	detector, common	„	1	7	0
	detector, 3-coil	„	1	13	0
	astatic ...	„	2	5	0
Glue	best...	lb.	0	0	8
	marine	„	0	0	6

Grapnels	cwt.	1	2	1
Gun-cotton	lb.	0	2	0
Indicators, for winding up apparatus	each	7	10	0
Ink, for Morse recorders	oz.	0	0	8
Jackets, wooden, for circuit closers	each	4	14	6
„ 100lb. electro-contact mines	„	2	12	8
Junction boxes, for 1 multiple and 7 single cables	„	0	19	3
Junction boxes, for multiple cable	„	0	3	6
Junction boxes, for single cable	„	0	2	6
Junction boxes, T, for branch mines	„	0	5	6
Keys, Firing	„	0	10	6
Keys, „ telescopic, for converging station		12	0	0
Keys, „ „ for firing station	„	14	10	0
Keys, reversing	„	3	0	0
Ladles, iron, melting, 1-quart	„	0	1	8
Lead, red, dry	cwt.	1	0	0
Lead, white, ground	„	1	5	4
Lime pencils, for Walker's light	box	0	3	6
Manganese, proxide	lb.	0	0	4
Manganese aud carbon mixture*	„	0	0	4
Mercury	80lbs. bottle	9	10	0
Nails (see vocabulary)	...			
Oil, colza	gal.	0	3	0
Oil, linseed, boiled	„	0	2	9
Oil, sweet	„	0	3	5
Paper, printing, for Morse recorders	rolls	0	0	6½
Paper, emery	quire	0	1	3
Paper, glass, coarse	„	0	0	8
Paper, glass, fine	„	0	0	8
Pitch	cwt.	0	8	6
Platinum wire, 1·65 gr. to yard	oz.	1	10	0
Pots, iron, melting	each	0	5	0
Potash, chlorate of	lb.	0	1	6
Recorders, Morse, Telegraph	each	21	0	0
Rope (see vocabulary)	...			
Rosin	cwt.	0	6	6
Sal-ammoniac	lb.	0	0	6
Shackles, iron, ½-inch	100	1	2	0
Signalling and firing apparatus, with 7 indices	each	16	0	0

* This mixture is a patent, the rights of which have been secured in this country, in connection with the well-known Leclanché Battery. It has hitherto been obtained at the School of Military Engineering, Chatham, for experimental purposes exclusively. It could only be obtained for actual work, in some form, under which the patent rights would be acknowledged.

Signalling apparatus, Walker's, visual, complete set, consisting of— 1 lime light; 2 lamps, signal, hand; 2 bags, gas; 1 bag, pressure; 2 retorts, copper; 1 bottle, wash; 1 pair scissors, lamp ...	set.	8	3	10
Sinkers { mushroom { 7-cwt. ... / 5 „ ... ; oblong { 3-cwt. ... / 2½ „ ... }	ton.	5	12	8
Solder, tinman's	lb.	0	0	8
Soldering irons	each	0	3	0
Solution, India-rubber	lb.	0	1	3
Sounder, portable, Morse, Telegraph	each	1	17	0
Sponges	½-oz.	0	0	6
Stamps (see vocabulary) ...	...			
Steelyards, 200-lbs.	each	0	13	0
Syringes, ebonite	„	0	10	0
Tapes, measuring, 100ft. ...	„	0	11	6
„ India-rubber	lb.	0	5	9
Tallow, Russian	cwt.	2	6	3
Tar, Stockholm	barrel	0	19	4
Test table, fittings for, sets, consisting of— 1 Commutator; 3 Keys, firing; 1 Pillar, for platinum wire; 12 Insulated discs; 10 „ terminals; 100 Double „	set.	12	15	0
Thimbles, iron, for wire rope ...	100	0	10	6
Tin, sheet (see vocabulary) ...	...			
Tools (see Vocabulary) ...	...			
Tools, for repairing instruments ...	sets	0	10	0
Trays, ebonite	each	0	8	0
Tubing, India-rubber { ⅜-inch ...	10ft.	0	2	8
Tubing, India-rubber { ½ „ ...	„	0	3	9
Turpentine, spirits of	gal.	0	2	6
Varnish { black	„	0	5	6
Varnish { shellac	„	0	12	0
Varnish { sealing wax ...	„	1	0	0
Wicks { cotton, lamp	doz.	0	0	10
Wicks { for Walker's light ...	lb.	0	1	2

Winding apparatus, with indicator		each	86	5	0
Wire	copper, 32 B.W.G. ...	lb.	0	2	0
	20 B.W.G., covd. with gutta percha to No. 14 B.W.G. ...	mile	8	0	0
	copper, 16 B.W.G., double covered with gutta percha to No. 7 B.W.G.	mile	22	0	0
	platinum—1·65 gr. to yard	oz.	1	10	0
Wire, rope, steel, in coils of 100 fathoms		cwt.	31	10	0
Wire, telegraph, insulated ...		knot	33	10	0
Steam engine for do.		each	135	0	0
Fair leads for do.		,,	3	15	0
Zinc, sheet, 15 B.W.G. ...		cwt.	1	16	0

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